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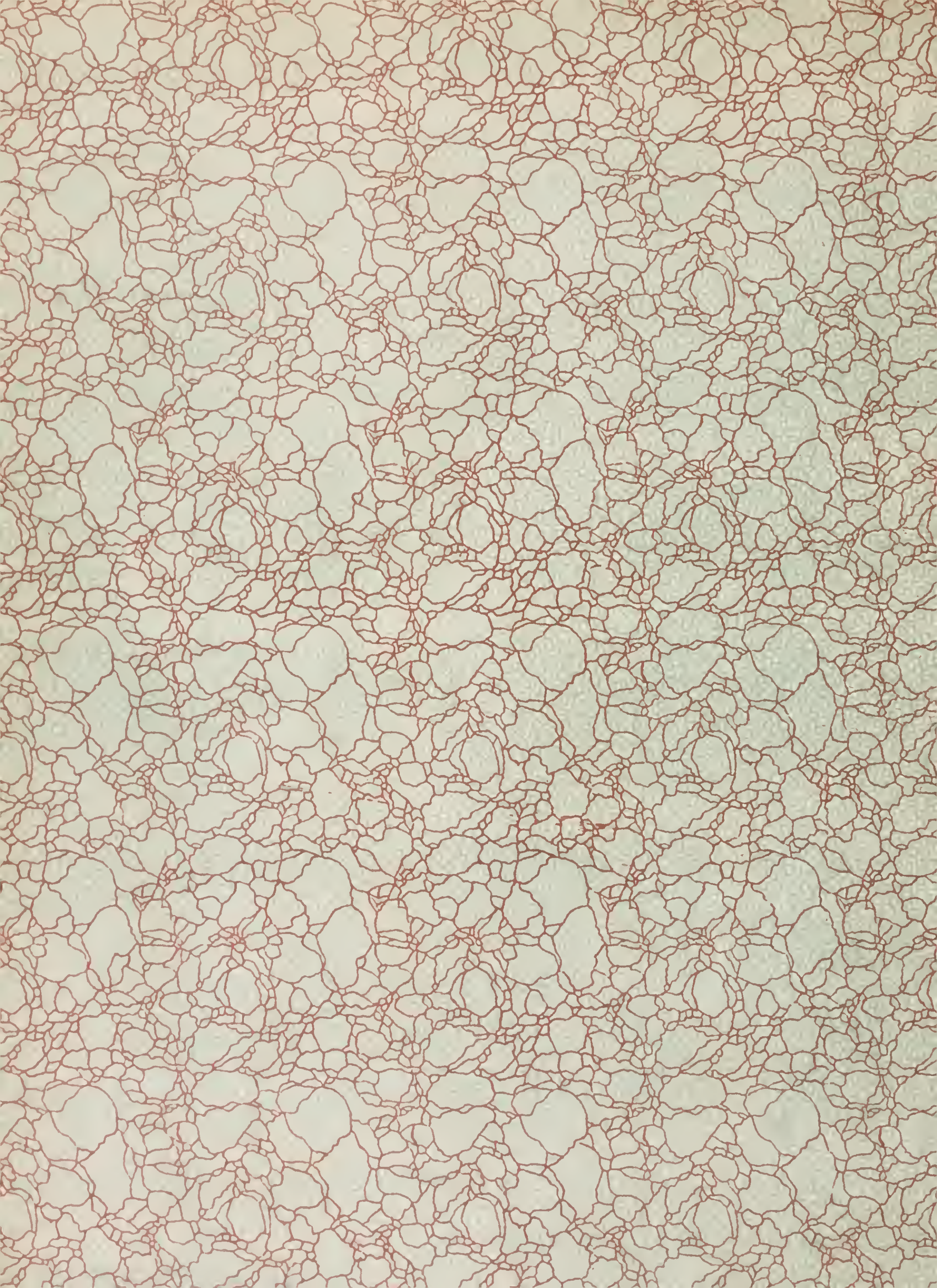

SMITHSONIAN INSTITUTION
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ASTEROIDEA OF THE NORTH PACIFIC AND ADJACENT WATERS

BY

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PART I. PHANEROZONIA AND SPINULOSA

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ADVERTISEMENT.

The scientific publications of the United States National Museum consist of two series, the *Proceedings* and the *Bulletins.*

The *Proceedings,* the first volume of which was issued in 1878, are intended primarily as a medium for the publication of original, and usually brief, papers based on the collections of the National Museum, presenting newly-acquired facts in zoology, geology, and anthropology, including descriptions of new forms of animals, and revisions of limited groups. One or two volumes are issued annually and distributed to libraries and scientific organizations. A limited number of copies of each paper, in pamphlet form, is distributed to specialists and others interested in the different subjects as soon as printed. The date of publication is printed on each paper, and these dates are also recorded in the table of contents of the volumes.

The *Bulletins,* the first of which was issued in 1875, consist of a series of separate publications comprising chiefly monographs of large zoological groups and other general systematic treatises (occasionally in several volumes), faunal works, reports of expeditions, and catalogues of type-specimens, special collections, etc. The majority of the volumes are octavos, but a quarto size has been adopted in a few instances in which large plates were regarded as indispensable.

Since 1902 a series of octavo volumes containing papers relating to the botanical collections of the Museum, and known as the *Contributions from the National Herbarium,* has been published as bulletins.

The present work forms No. 76 of the *Bulletin* series.

RICHARD RATHBUN,
Assistant Secretary, Smithsonian Institution,
In charge of the United States National Museum.

WASHINGTON, D. C., MAY 4, 1911.

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ASTEROIDEA OF THE NORTH PACIFIC AND ADJACENT WATERS.

By Walter Kenrick Fisher,
Assistant Professor of Zoology, Stanford University, California.

PART 1. PHANEROZONIA AND SPINULOSA.

INTRODUCTION.

The region covered by the present report embraces the western coast of North America from the thirty-second parallel of latitude to Point Barrow on the Arctic Ocean, all of Bering Sea, the coast of Asia from East Cape to Sakhalin, and the Kuril Islands. It thus includes all the waters north of a line drawn from the southern end of Sakhalin to the southern boundary of the United States. Information concerning the fauna of the Sea of Okhotsk is very meager; and within the region outlined nothing is known concerning the starfishes of the great depths of the mid North Pacific.

In the preparation of this report six thousand nine hundred and twenty-seven specimens have been listed, and many more examined. These specimens belong to the following collections:

1. The very extensive collection of the U. S. National Museum, the bulk of which was obtained by the U. S. Fisheries steamer *Albatross* between 1888 and 1897, inclusive. The dredge hauls at which Asteroidea were taken number about two hundred, and the specimens listed number four thousand three hundred and eighty. Many specimens were taken by Dr. W. H. Dall and others in Alaska.

2. A collection made by the *Albatross* in Alaska in 1903, and forwarded to me for report by the U. S. Bureau of Fisheries.

3. A large collection made by the *Albatross* off California, principally in the regions off San Diego and Monterey, during the spring of 1904, and sent to me by the U. S. Bureau of Fisheries.

4. A collection made by the *Albatross* during the summer of 1906, in the region of the Aleutian Islands, Kamchatka, and the Kuril Islands.

5. A small collection, principally from off San Pedro, California, and belonging to the University of California, kindly lent by Prof. W. E. Ritter.

6. The small collection of the Department of Zoology, Stanford University, principally from Alaska, and Monterey, California.

7. The Museum of Comparative Zoölogy, through Dr. H. L. Clark, has lent several specimens for examination.

I had completed special reports on collections Nos. 2 and 3 when the collection from the U. S. National Museum, sent by Dr. Richard Rathbun, Assistant Secretary of the Smithsonian Institution, was received. This is probably the largest and most complete single collection ever assembled from a restricted region (the west coast of North America). Doctor Rathbun at one time contemplated working up this material, and to that end made a preliminary sorting of specimens in several groups. He was, however, prevented by routine work from carrying out his plans.

In view of this new accession, it was deemed best not to publish separate papers on the Alaskan and Californian collections, but to combine all in one report. Under each species the source of the material is in all cases given in the lists of specimens examined, so that it is easy to ascertain from which of the several collections the information was derived.

The material proved to be richer than was anticipated, and it has been necessary to issue the work in two parts, of which this is Part 1. Part 2 will contain an account of the order Forcipulata.

In 1907 I examined, through the courtesy of Mr. Samuel Henshaw and Dr. H. L. Clark, the extensive collection of starfishes in the Museum of Comparative Zoölogy, Cambridge, Massachusetts. This collection contains many types and includes numerous genera not in the national collection. Prof. A. E. Verrill, of Yale University, New Haven, Connecticut, kindly showed me many of his types, especially those of his new genera of Goniasteridæ, Astropectinidæ, and Goniopectinidæ.

At Washington I examined all of the national collection, with a view to determining, if possible, the relationships of genera and families, a subsidiary task of the present work.

Since many genera had never been assigned a definite type, I made a list of all the genera of Asteroidea with their type-species in order to render the nomenclature of the present report as stable as possible. This necessitated drawing upon the resources of the following libraries: those of the National Museum and Smithsonian Institution, the Congressional, Army Medical, Philadelphia Academy of Natural Sciences, Museum of Comparative Zoölogy, and the private library of Dr. C. Hart Merriam. The nomenclature follows without compromise the rules of the International Code. It has been necessary in a few cases to alter familiar names, because they have long been incorrectly applied. It is not anticipated that this course will greatly inconvenience anyone.

In the preparation of this paper several objects have been kept in mind. These are as follows:

1. To describe and figure all forms known to occur in the region covered by this report in such a manner that reference to the scattered literature will not be necessary. It has not been possible, however, to figure a few species, as specimens were not accessible:

2. To throw as much light as possible on the morphology, especially whenever this promised to lend aid to classification. A good many forms, especially in the Astropectinidæ and Goniasteridæ, have been examined with this object in view:

3. To revise the classification of genera and families and to work toward as natural a system as possible:

4. To describe the variations of the different forms represented as thoroughly as the material would permit. In many instances large series of specimens emphasized in a very striking manner the wide and remarkable variations which characterize most species of Asteroidea:

5. To describe the young stages of the different forms:

6. To consider the affinities of the Asteroidea of the North Pacific to the Asteroidea of other regions; under each species the geographical distribution is given, and, whenever possible, its probable relationships are considered in detail:

7. To present keys to all the families of Asteroidea, and to all the genera of every family represented in the region under consideration. Care has been exercised to eradicate the numerous errors of current keys, but it is too much to hope that mistakes do not still persist. A considerable portion of the time spent in completing this report has been consumed in verifying structural details in genera not directly considered; but, as genera have greatly multiplied in the last ten years, it is believed that these keys will prove useful to students of Asteroidea.

In these days it is impossible to complete a piece of systematic work without the aid of others, and it becomes a pleasant duty to acknowledge this cooperation, always cheerfully rendered.

Dr. Richard Rathbun, Assistant Secretary of the Smithsonian Institution, in charge of the U. S. National Museum, has allowed the freest use of all material in the museum under his charge, and forwarded the extensive collection upon which this report is primarily based. As previously stated, Doctor Rathbun at one time contemplated preparing a report on this collection. Throughout the progress of the work Doctor Rathbun has rendered every possible aid. In 1907 I worked for a few months at Washington and Cambridge under a grant from the National Museum.

I am under obligations to Dr. H. L. Clark, Mr. Samuel Henshaw, and Prof. A. E. Verrill for the privilege of examining collections in their charge. Doctor Clark subsequently sent several specimens for examination, and Professor Verrill examined for me specimens of *Solaster* and forwarded photographs of several of his new species.

The U. S. Bureau of Fisheries has allowed the use of its collections made during three cruises of the *Albatross* under the direction of Doctors Jordan and Evermann (1903), Doctors Jordan and Gilbert (1904), and Doctor Gilbert (1906).

To Dr. Theodore Gill, Dr. D. S. Jordan, Dr. L. Stejneger, Mr. H. C. Oberholser, and Mr. Austin Hobart Clark I am indebted for advice and aid in untangling nomenclatural knots. Mr. Clark has not only looked up literature inaccessible to me, but also both he and Miss Mary J. Rathbun have greatly aided me by reading a set of proofs.

Perhaps not least important has been the encouragement I have received from Doctor Jordan and Doctor Gilbert, for the course of the systematist lies rather more frequently through briar tangles and over rough places than where the way is open and fair.

The drawings and negatives of the photographic illustrations were made by the writer. The prints of the latter were made by Mr. T. W. Smillie, of the U. S. National Museum.

CLASSIFICATION OF THE ASTEROIDEA.

In this paper an attempt has been made to combine the best features of the classifications of Sladen, Perrier, and Verrill, but the results of my own work have led me to modify my former scheme (1906) in many important details. The Astropectinidæ has been enlarged and the Plutonasteridæ abandoned, a part of its genera going to the Astropectinidæ, a part to the Benthopectinidæ, and *Mimaster* to the Goniasteridæ. It was a very unnatural group and the reasons for the change are discussed under the Astropectinidæ. The Goniasteridæ has been enlarged to include the old family Antheneidæ and a new subfamily for *Chitonaster* has been instituted. *Chætaster* has been removed from the Linckiidæ and regarded as a separate family, Chætasteridæ Ludwig, 1897. The Acanthasterinæ and Valvasterinæ have been raised to family rank.

The weakest point in every scheme of classification of the Asteroidea is between the Phanerozonia and Spinulosa. Under the latter order Perrier ranges *Porania* and its allies in the Poraniidæ, while *Dermasterias, Asterope*, and *Petricia* are placed in the Phanerozonia, or rather Valvata. I have merged the Poraniidæ with the Asteropidæ (Gymnasteriidæ of authors) as a phanerozoniate family. Sladen regards *Asterina* and its allies as belonging to the Phanerozonia. I have placed them in the Spinulosa, following Perrier's system. Sladen classifies the Linckiidæ in the Cryptozonia near Zoroasteridæ; I have placed the family in the Phanerozonia. The meaning of this is that no sharp line exists between the Phanerozonia and Spinulosa. It is, however, not at all difficult to separate the Forcipulata from the Spinulosa.

In grouping the families I have followed as nearly as a lineal arrangement will permit what seems to be the most natural order, but there are two or three other combinations which are probably just as "natural." The Porcellanasteridæ are placed first to avoid sandwiching them between the Astropectinidæ and some other family, and because they stand apart from the other Phanerozonia.

The following classification is used in this paper:

ECHINODERMA ASTRORADIATA.

Class ASTEROIDEA.

Order PHANEROZONIA.

Family PORCELLANASTERIDÆ.
  Subfamily PORCELLANASTERINÆ.
  Subfamily CTENODISCINÆ.
Family GONIOPECTINIDÆ.
Family ASTROPECTINIDÆ.
Family LUIDIIDÆ.
Family BENTHOPECTINIDÆ.
Family ARCHASTERIDÆ.
Family CHÆTASTERIDÆ.
Family ODONTASTERIDÆ.
Family GONIASTERIDÆ.
  Subfamily MIMASTERINÆ.
  Subfamily PSEUDARCHASTERINÆ.
  Subfamily NECTRIINÆ.

  - Subfamily GONIASTERINÆ.
  - Subfamily HIPPASTERIINÆ.
  - Subfamily LEPTOGONASTERINÆ.
  - Subfamily CHITONASTERINÆ.
  - Subfamily ANTHENEINÆ.
- Family OREASTERIDÆ.
- Family LINCKIIDÆ.
- Family ASTEROPIDÆ.

Order SPINULOSA.

- Family GANERIIDÆ.
- Family ASTERINIDÆ.
  - Subfamily ASTERININÆ.
  - Subfamily ANSEROPODINÆ.
  - Subfamily TREMASTERINÆ.
- Family ECHINASTERIDÆ.
- Family ACANTHASTERIDÆ.
- Family MITHRODIIDÆ.
- Family VALVASTERIDÆ.
- Family CRYASTERIDÆ.
- Family SOLASTERIDÆ.
- Family KORETHRASTERIDÆ.
- Family MYXASTERIDÆ.
  - Subfamily PYTHONASTERINÆ.
  - Subfamily MYXASTERINÆ.
- Family PTERASTERIDÆ.

HISTORY OF SYSTEMATIC WORK ON NORTH PACIFIC ASTEROIDEA.

As compared with the North Atlantic, little work has been done on the Asteroidea of the region under consideration, notwithstanding that the west coast of North America is more prolific in species and individuals than any other portion of the world. The littoral fauna is especially well developed, and the family Asteriidæ contains a surprisingly large number of forms. The following sketch is intended to serve merely as an historical outline and not as a complete summary of every paper published. The full titles are given under the Bibliography.

The earliest as well as one of the most important papers was the Prodromus of Brandt which appeared in 1835 and contained short Latin diagnoses of starfishes collected by H. Mertens in the vicinity of Sitka, Bering Strait, and Kamchatka. The new forms named by Brandt are:

Asterias miniata.
Asterias ochracea.
Asterias janthina.
Asterias epichlora.
Asterias camchatica.
Asterias pectinata.
Asterias helianthoides.
Asterias affinis.
Asterias alboverrucosa.
Asterias endeca, var. *decemradiata.*

In the Annals and Magazine of Natural History, volume 6, November, 1840, J. E. Gray described *Asterias katherinæ* from the mouth of the Columbia River.

Müller and Troschel, in their System der Asteriden, 1842, described *Asteracanthion margaritifer*, which is synonymous with *Pisaster ochraceus* (Brandt).

In Middendorff's Reise in den äussersten Norden und Osten Siberiens, 1851, Brandt described, from the Okhotsk region, *Asteracanthium ochotense*, near *A. rubens*, with two varieties (*a*) *macrobrachia*, (*b*) *brachybrachia*.

In 1857, Edward Grube, in his Beschreibungen neuer oder weniger bekannter Seesterne und Seeigel, described and figured *Asteropsis imbricata*, collected by Dr. Wilhelm von Bock at Sitka.

In 1857, William Stimpson, in the Boston Journal of Natural History, volume 6, described *Asterias gigantea*, Tomales Bay, California, *Asterias brevispina*, San Francisco Bay (both *Pisaster*), *Linckia leviuscula* (*Henricia*), Puget Sound, and the new genus and species *Mediaster æqualis*, Puget Sound.

This article was followed in 1862 by a paper in the Proceedings of the Boston Society of Natural History, volume 8, in which the following west coast forms were diagnosed:

Asterias acervata, Bering Strait.
Asterias æqualis, Monterey.
Asterias capitata, San Diego.
Asterias conferta, Puget Sound.
Asterias cribraria, north of Bering Strait.
Asterias fissispina, Shoal Water Bay, Oregon.
Asterias hexactis, Puget Sound.
Asterias lütkenii, coast of Oregon.
Asterias paucispina, Puget Sound.
Asterias troschelii, Puget Sound.

In 1865 Edward Grube in an article entitled, Ueber einige Seesterne des Breslauer Museums, described, without locality, *Chætaster californicus*. This species is possibly *Henricia leviuscula*.

In the following year he diagnosed *Luidia foliolata* (the *L. foliata* of Sladen), without locality.[a]

In July, 1867, A. E. Verrill published an important article On the Geographical Distribution of Echinoderms of the Pacific Coast of America.[b]

The following species are listed from Sitka: *Asteropsis imbricata* Grube, *Patiria miniata* (Brandt), *Solaster decemradiatus* (Brandt) Stimpson, *Pycnopodia helianthoides* (Brandt), *Asterias epichlora* Brandt, *Asterias ochracea* Brandt. The following are stated to occur in Puget Sound and along the coast to Cape Mendocino: *Mediaster æqualis* Stimpson, *Patiria miniata*, *Cribrella leviuscula* (Stimpson), *Pycnopodia helianthoides*, *Asterias epichlora*, *A. ochracea*, *A. conferta* Stimpson, *A. fissispina* Stimpson, *A. lütkenii* Stimpson, *A. paucispina* Stimpson, *A. troschelii* Stimpson, *A. hexaxtis* Stimpson. The following species are listed as occurring between Cape Mendocino and San Diego: *Mediaster æqualis*, *Patiria miniata*, *Pycnopodia helianthoides*, *Asterias gigantea* Stimpson, *A. brevispina* Stimpson, *A. ochracea*, *A. capitata* Stimpson, *A. æqualis* Stimpson.

For nearly ten years no new species were characterized. Perrier in his Révision des Stellérides (1875) diagnosed two new forms, *Asterias brachiata* from the Gulf of Georgia,[a] and *Asterias vancouveri* from Esquimalt Harbor, Vancouver Island. The latter was briefly described in the Annals and Magazine of Natural History.[b] Here also was named, with very insufficient description, *Asterias douglasi*, which had been confused, in the British Museum, with the true *Asterias katherinæ* Gray, from the mouth of the Columbia. *A. douglasi* was without locality and probably does not belong to our region. It is fully described in the Revision.

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[a] 43 Jahresber. schles. Ges. vaterl. Cultur, Breslau, 1866, p. 59.

[b] Trans. Connecticut Acad. Arts and Sci., vol. 1, pt. 2, p. 323.

In an article entitled Étude sur la répartition géographique des Astérides[c] Perrier named but did not diagnose *Luidia californica*, a species mentioned but not described by Lütken.[d] The name is a *nomen nudum*.

A. E. Verrill, in 1880, described *Archaster* (now *Luidiaster*) *dawsoni* from off the Queen Charlotte Islands, 111 fathoms, *Solaster stimpsoni* from Ramsay Island, British Columbia, and *S. dawsoni* from 8 to 15 fathoms Virago Sound, British Columbia, in an article by J. F. Whiteaves entitled: Appendix C. On Some Marine Invertebrata from the Queen Charlotte Islands.[e]

In Ray's report of the international polar expedition to Point Barrow, Alaska. 1885, John Murdoch listed six species of starfishes, of which one was described as new, *Leptasterias arctica*, from off Point Franklin, 13½ fathoms.

In the following year H. Ludwig published the first important article dealing with the echinoderms of Bering Sea. He listed six starfishes, of which *Ctenodiscus krausei* (=*crispatus*) and *Pteraster aporus* (=*militaris*) were characterized as new.[f]

P. de Loriol, in Notes pour servir à l'étude des Échinodermes, II, described two[g] new species collected by Alphonse Forrer at Santa Cruz, California: *Asterias forreri* and *A. exquisita*.

In 1888 J. E. Ives described *Pteraster tesselatus* from Kadiak Island.[h] In 1892 the same writer published privately a List of the Echinoderms and Crustacea in the Cabinet of Frederick Stearns, Detroit, Michigan. On page ii is a list of west coast Asteroidea, but no new species. I am indebted to Prof. A. E. Verrill for information concerning this paper.

In the Proceedings of the U. S. National Museum for 1894, page 268, A. E. Verrill characterized *Acantharchaster*, new genus, with *Archaster dawsoni* for type.

P. de Loriol in a fifth paper of his Notes pour servir à l'étude des Échinodermes[i] admirably described and figured seven species from Saanich Inlet, Vancouver Island, three of them new:

Crossaster vancouverensis. | *Asterias kœhleri.*
Asterias saanichensis.

In May, 1901, an important paper by H. L. Clark appeared in the Proceedings of the Boston Society of Natural History, volume 29, pages 323-329 (Asteroidea), on Echinoderms from Puget Sound: Observations made on the Echinoderms collected by the parties from Columbia University, in Puget Sound in 1896 and 1897. Eight species of starfishes are listed, of which three, *Pteraster multispinus*, *Retaster gracilis*, and *Cribrella spiculifera*, are new; and two new varieties of *Cribrella læviuscula* are characterized: *C. læviuscula crassa* and *C. læviuscula attenuata*. There is reason to believe that *Echinaster tenuispinus* was not from Puget Sound. I am informed that specimens from the West Indies became mixed with the original Puget Sound collection before it was sent to Doctor Clark.

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[a] Specimens in the Museum of Comparative Zoölogy, as for example, No. 1191 are so labeled. Perrier's specimen came from this Museum.

[b] Ser. 4, vol. 17, Jan., 1876, p. 187.

[c] Nouv. arch. du mus. d'hist. nat. Paris, ser. 2, vol. 1, 1878, pp. 35 and 91.

[d] Vid. Medd., 1871, p. 229.

[e] Report of Progress; Geol. Survey of Canada for 1878-79, 1880.

[f] Echinodermen des Beringsmeeres, Zool. Jahrb., Abth. Syst., vol. 1, 1886, pp. 287-295.

[g] Rec. zool. Suisse, vol. 4, No. 3, June 23, 1887.

[h] Proc. Acad. Nat. Sci. Philadelphia, p. 421.

[i] Mémoires soc. phys. et d'hist. nat. Genève, vol. 32, 1897.

Up to 1905 the fauna of the deep water off the west coast of North America was practically unknown, for only one species had been described (*Archaster dawsoni*, by Verrill, 1880), although a wealth of material had been accumulating in the U. S. National Museum since 1888, as a result of the numerous cruises of the U. S. Fisheries steamer *Albatross*.

In the Bulletin of the Bureau of Fisheries for 1904, volume 24, June 10, 1905, W. K. Fisher described one new genus, two new subgenera, and twenty-four new species based upon collections made by the *Albatross* in Alaskan waters during the summer of 1903 and off the coast of southern and central California in 1904, as follows:

Eremicaster, new subgenus.
Porcellanaster (*Eremicaster*) *tenebrarius*.
Bathybiaster pectinatus.
Dipsacaster eximius.
Persephonaster penicillatus.
Benthopecten acanthonotus.
Dytaster gilberti.
Mimaster swifti.
Odontaster crassus.
Pseudarchaster alascensis.
Pseudarchaster pusillus.
Tosia leptocerama.
Mediaster tenellus.
Hippasteria heathi.
Hippasteria californica.
Cryptopeltaster, new genus.
Cryptopeltaster lepidonotus.
Lophaster furcilliger.
Peribolaster biserialis.
Pteraster jordani.
Hymenaster quadrispinosus.
Zoroaster ophiurus.
Myxoderma, new subgenus.
Zoroaster (*Myxoderma*) *sacculatus*.
Zoroaster (*Myxoderma*) *evermanni*.
Brisinga exilis.
Freyella fecunda.

Although not directly concerned with the region under consideration, the report by H. Ludwig on the Asteroidea collected off the Galapagos Islands, Mexico, Central and South America, by the *Albatross* in 1891, is of importance because some of his new species occur as far north as Alaska (as, for instance, *Porcellanaster pacificus*, *P. waltharii* (= *Eremicaster tenebrarius* Fisher) and *Plutonaster abyssicola* (= *Psilaster pectinatus* Fisher). Others are very closely related to forms described in the following report. Ludwig's paper appeared July 17, 1905, as volume 32 of the Memoirs of the Museum of Comparative Zoölogy.

In the Zoologischer Anzeiger for June 19, 1906, W. K. Fisher described *Astropecten californicus* and *Alexandraster inflatus* (= *Poraniopsis inflata*) from Monterey Bay; and in New Starfishes from the Pacific Coast of North America,[a] one new genus and ten new species, based on the National Museum collection, were characterized:

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[a] Proc. Washington Acad. Sci., vol. 8, 1906, pp. 111-139.

Leptychaster pacificus.
Leptychaster anomalus.
Astropecten ornatissimus.
Luidia ludwigi.
Luidia asthenosoma.
Henricia aspera.
Henricia polyacantha.
Crossaster (now *Heterozonias*) *alternatus.*
Crossaster (now *Solaster*) *borealis.*
Rathbunaster californicus (new genus).

H. Ludwig in the Zoologischer Anzeiger for March 5, 1907 (p. 317), raised *Eremicaster* Fisher to a full genus and changed the type to *Porcellanaster crassus* Sladen. In the same journal for July 23, 1907, W. K. Fisher criticised the characters used by Ludwig to separate *Eremicaster* from *Porcellanaster* and called attention to the fact that this writer had no power to change an established type-species, which is *tenebrarius*, not *crassus*.

In the Smithsonian Miscellaneous Collections (Quarterly Issue), volume 52, May 27, 1908, W. K. Fisher called attention to a number of generic names which had long been incorrectly used, and proposed substitute names. The changes instituted, some of which affect the nomenclature of the present paper, were as follows:

Anasterias Perrier has precedence over *Sporasterias.*
Anasterias Ludwig (*not* Perrier) becomes *Lysasterias* Fisher.
Gymnasteria Gray becomes *Asterope* Müller and Troschel.
Asteropsis of authors (*not* Müller and Troschel) becomes *Petricia* Gray.
Crenaster Perrier (*not* d'Orbigny) becomes *Dytaster* Sladen.
Ctenaster Perrier (*not* Agassiz) becomes *Lætmaster* Fisher.
Diplasterias Perrier is a synonym of *Pisaster* Müller and Troschel.
Goniodon Perrier (antedated by *Goniodon* Herrick) becomes *Diplodontias* Fisher.
Patiria Gray is a synonym of *Asterina* Nardo.
Patiria Perrier (*not* Gray) becomes *Parasterina* Fisher.
Pararchaster Sladen is a synonym of *Benthopecten* Verrill.
Pentaceros Schulze (nonbinomial) becomes *Oreaster* Müller and Troschel.

The same facts were published in the Zoologischer Anzeiger for August 18, 1908.

A. E. Verrill, in Descriptions of the New Genera and Species of Starfishes from the North Pacific Coast of America,[a] diagnosed the following forms:

Solaster galaxides, Victoria, British Columbia.
Solaster constellatus, Puget Sound.
Pteraster octaster, Bering Island.
Pteraster hebes, Departure Bay, British Columbia.
Hippasteria spinosa, Departure Bay, British Columbia.
Tosia arctica, Bering Island.
Asterias (*Pisaster*) *papulosa*, Vancouver Island.
Allasterias rathbuni (new genus and species) Maloska.
Asterias (*Urasterias*) *forcipulata*, Departure Bay, British Columbia.
Asterias polythela, Arctic coast of Alaska.
Asterias victoriana, Victoria, British Columbia.

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[a] Amer. Journ. Sci., July, 1909, pp. 59-70.

In a general article in the American Naturalist for September, 1909, entitled Remarkable Development of Starfishes on the Northwest American Coast; Hybridism; Multiplicity of Rays; Teratology; Problems in Evolution; Geographical Distribution, the same writer named a number of new genera and species, some without description, some with a few lines of description, and three with figures.

New Genera.

Pterasterides for *Pteraster aporus* Ludwig.
Glyphaster for *Leptychaster anomalus* Fisher.
Bunodaster for *B. ritteri* Verrill, "California."

New Species.

Asterias acanthostoma.
Asterias dubia.
Asterias epichlora, var. *alaskensis.*
Leptychaster millespina.
Henricia tumida.
Henricia spatulifera.

Nomina Nuda.

Asterias columbiana.
Asterias troschelii, var. *rudis.*
Asterias forcipulata.
Asterias macropora.
Henricia sanguinolenta, var. *pectinata.*

In the Annals and Magazine of Natural History for February, 1910, W. K. Fisher published diagnoses of *Thrissacanthias*, *Gephyreaster*, *Sphæriodiscus*, and *Heterozonias*, new genera, and preliminary diagnoses of *Pteraster trigonodon*, *Pt. coscinopeplus*, *Pt. marsippus*, *Pt. temnochiton*, *Hymenaster kahleri*, and *H. perissonotus*. In the Zoologischer Anzeiger for March 29, 1910, twenty-four new species and subspecies were characterized, as follows:

Leptychaster propinquus.
Dipsacaster borealis.
Dipsacaster lætmophilus.
Dipsacaster anoplus.
Benthopecten claviger.
Benthopecten mutabilis.
Acantharchaster aciculosus.
Acantharchaster variabilis.
Acantharchaster variabilis pedicellaris.
Acantharchaster intermedius.
Cheiraster agassizi evoplus.
Pseudarchaster dissonus.
Ceramaster clarki.
Cladaster validus.
Hippasteria leiopelta.
Poraniopsis inflata flexilis.
Henricia leviuscula multispina.
Henricia leviuscula annectens.
Henricia asthenactis.
Henricia longispina.
Henricia clarki.
Solaster exiguus.
Solaster hypothrissus.
Lophaster furcilliger vexator.

DISTRIBUTION AND RELATIONSHIPS OF NORTH PACIFIC ASTEROIDEA.

A full account of the distribution of species must be reserved for the concluding installment of this paper. It is intended here to present only the main features of the relationships and distribution of the Phanerozonia and Spinulosa. Tables of the bathymetrical range of species will also be given in a subsequent report.

Before commenting upon the distribution it will be necessary to present a few tables.

1. Species common to North Pacific and North Atlantic.

Ctenodiscus crispatus.
Leptychaster arcticus.
Pseudarchaster parelii.
Henricia sanguinolenta.
Henricia s. eschrichtii.
Solaster endeca.
Solaster papposus.
Lophaster f. vexator?
Pteraster militaris.
Pteraster obscurus.
Pteraster pulvillus.
Diplopteraster multipes.

2. Species common to North Pacific and South Pacific.

Ctenodiscus crispatus.
Ceramaster patagonicus.

3. Species common to west coast of North America and Japan.[a]

(Those marked with an asterisk are found also in the North Atlantic; circumpolar species.)

*Ctenodiscus crispatus.**
*Leptychaster arcticus.**
Leptychaster anomalus.[b]
*Pseudarchaster parelii.**
Ceramaster japonicus.[b]
*Henricia sanguinolenta.**
Solaster paxillatus.[b]
Solaster borealis.[b]
Solaster dawsoni (var.)[b]
*Diplopteraster multipes.**

4. Species found on the west coast of North America and extending south along Mexico and Central and South America.

Eremicaster tenebrarius, to Galapagos Islands.
Eremicaster pacificus, to Gulf of Panama and Galapagos Islands.
Ctenodiscus crispatus, to southern end of South America.
Psilaster pectinatus, to Gulf of Panama.
Astropecten armatus[c], to Ecuador.
Astropecten californicus, to Lower California.
Luidia foliolata, to Mazatlan.
Benthopecten acanthonotus, possibly to Galapagos Islands.
Mediaster tenellus, possibly to Panama.
Cryptopeltaster lepidonotus, to Tres Marias Islands, Mexico.
Linckia columbiæ,[c] to Colombia and Galapagos Islands.
Asterina miniata, to Gulf of California.
Poraniopsis inflata flexilis, probably to Galapagos Islands.

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[a] Doctor S. Goto's list of Japanese deep-water forms has not been published; the species listed are those I have personally examined. This list should be augmented when the report on the *Albatross* collection of 1906 is published.

[b] Not found outside the North Pacific.

[c] Intrusions into the United States fauna from the Panamic fauna, and shallow-water species. The rest, with the exception of *Luidia foliolata*, *Astropecten californicus*, and *Asterina miniata*, are deep-water forms.

Lophaster furcilliger, to Galapagos Islands.
Hymenaster quadrispinosus, probably to vicinity of Panama.

5. GENERA PECULIAR TO THE NORTH PACIFIC.[a]

Thrissacanthias (extends into Japanese waters).
Bunodaster Verrill (probably synonymous with *Blakiaster*).
Nearchaster.
Myonotus.
Gephyreaster.
Dermasterias.
Cryptopeltaster.
Heterozonias.

6. SPECIES PECULIAR TO THE NORTH PACIFIC; THEIR DISTRIBUTION AND PROBABLE AFFINITIES.[b]

Species.	Okhotsk Sea, Kamchatka, Kurils.	Bering Sea.	Aleutian Islands to Kadiak.	Kadiak to Sitka.	Sitka to Puget Sound.	Puget Sound to Monterey Bay.	South of Monterey Bay.	Related species.
Leptychaster propinquus	×[c]							*L. anomalus.*
Leptychaster anomalus[d]	×	×	×	×	×	×		*L. inermis* (Ludwig.)
Leptychaster pacificus		×	×	×	×			*L. arcticus.*
Astropecten californicus						×	×[e]	*A. fragilis?*
Astrapecten ornatissimus							×[e]	
Thrissacanthias penicillatus						×	×	A Japanese species.
Dipsacaster eximias							×	*D. borealis.*
Dipsacaster borealis		×	×					*D. eximius.*
Dipsacaster lætmophilus				×				*D. nesiotes.*
Dipsacaster anoplus						×	×	
Dytaster gilberti							×	*D. exilis.*
Luidia foliolata					×	×	×	*L. brevispina.*
Luidia ludwigi							×	*L. lorioli.*
Luidia asthenosoma[f]							×	*L. sarsi.*
Pectinaster a. evoplus							×	*P. agassizi, P. mimicus.*
Luidiaster dawsoni	×[c]	×	×	×	×			*L. horridus.*
Nearchaster aciculosus				×		×	×[e]	
Nearchaster variabilis		×	×		×			*N. aciculosus.*
Nearchaster pedicellaris			×					*N. variabilis.*
Myonotus intermedius						×[g]		
Benthopecten claviger		×	×			×		
Benthopecten mutabilis					×			*B. spinosus.*
Odontaster crassus							×	*O. grayi.*
Gephyreaster swifti			×		×			
Pseudarchaster p. alascensis				×	×	×[h]		
Pseudarchaster pusillus							×[f]	*Ps. pulcher.*
Pseudarchaster dissonus						×		*Ps. pectinifer.*
Mediaster æqualis				×	×	×	×[e]	
Ceramaster leptoceramus							×	
Ceramaster japonicus[i]		×	×		×[j]			

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[a] *Glyphaster* Verrill, and *Pterasterides* Verrill, I do not accept.

[b] *Bunodaster ritteri* Verrill is not included. It is stated to occur in "California." Probably its range should be given as south of Monterey Bay.

[d] Commander Islands only, not off the mainland.

[c] Ranges to Sea of Japan.

[e] To Lower California.

[f] From north of Monterey Bay to Los Coronados Islands, Lower California.

[g] Monterey Bay only.

[h] To Oregon.

[i] To Japan.

[j] To Washington.

6. Species peculiar to the North Pacific; their distribution and probable affinities—Con.

Species.	Okhotsk Sea, Kamchatka, Kurils.	Bering Sea.	Aleutian Islands to Kadiak.	Kadiak to Sitka.	Sitka to Puget Sound.	Puget Sound to Monterey Bay.	South of Monterey Bay.	Related species.
Ceramaster clarki		×					×	
Ceramaster arcticus	×[a]	×	×					
Cladaster validus			×					*C. rudis.*
Hippasteria spinosa				×	×	×	×	*H. phrygiana.*
H. s. kurilensis	×[b]							
H. leiopelta	×							
H. l. armata	×[b]							
H. heathi					×			
H. californica						×	×	
Cryptopeltaster lepidonotus							×[c]	
Dermasterias imbricata					×	×		
Asterina miniata					×	×	×[d]	*A. pectinifera.*
Poraniopsis inflata						×	×	*P. echinaster.*
Henricia leviuscula			×	×	×	×	×	
Henricia l. annectens						×	×	
Henricia l. multispina	×[b]	×	×	×	×	×		
Henricia l. dyscrita							×	
Henricia aspera	×[a]	×	×	×	×	×	×	
Henricia spiculifera					×			
Henricia asthenactis	×	×	×				×	
Henricia longispina					×			
Henricia l. aleutica			×					
Henricia polyacantha							×	
Henricia clarki							×[e]	*H. pauperrima.*
Solaster stimpsoni	×[a]			×	×	×		*S endeca.*
Solaster dawsoni[f]	×		×		×	×		
Solaster paxillatus[g]	×	×	×	×				*S. syrtensis*(?)
Solaster exiguus							×	*S. paxillatus.*
Solaster borealis[g]		×	×	×	×	×	×	*S. australis.*
Solaster hypothrissus			×					*S. borealis.*
Heterozonias alternatus						×	×	
Peribolaster biserialis	×[a]	×	×					
Pteraster trigonodon							×	
Pteraster jordani						×	×	
Pteraster marsippus	×[a]	×	×					*Pt. jordani.*
Pteraster coscinopeplus							×	
Pteraster temnochiton			×					
Pteraster multispinus					×			*Pt. reticulatus.*
Pteraster gracilis					×			
Pteraster tesselatus	×[a]	×	×		×			
Pteraster t. arcuatus						×		
Hymenaster kœhleri		×						*H. nobilis.*
Hymenaster perissonotus		×			×	×	×	

[a] Commander Islands only, not off the mainland.
[b] Simushir, Kuril Islands.
[c] To the Tres Marias Islands.
[d] To Lower California.
[e] To the Revillagigedo Islands, Mexico.
[f] Through Bering Strait.
[g] To Japan.

Of the ninety-six species and subspecies listed, seventy-three, or over 76 per cent, are confined to the North Pacific, although five of these extend to Japan (Table 3) and six others to Mexican waters but not beyond the Tres Marias and Revillagigedo islands, leaving 61 per cent confined within the geographical limits of this report.

Of the remaining twenty-three species, twelve are found in the North Atlantic; and of these twelve, one (*Ctenodiscus crispatus*) extends also to Japan and to the South Pacific (Tables 1 and 2), while four others range into Japanese waters. The other eleven species are part of another fauna and their ranges extend southward variously to Panama, the Galapagos Islands, Ecuador, and the extremity of South America. If *Ctenodiscus crispatus*, a very wide ranging form, is omitted it will be seen that eleven of the species are derived from the North Atlantic fauna and eleven others from the South American.

Of the latter eleven, two species belong to the shallow water Panamic fauna and have pushed northward into southern California. They are—

Astropecten armatus.
Linckia columbiæ.

Considering the seventy-three species which are confined to the North Pacific, only four (*Leptychaster propinquus, Hippasteria spinosa kurilensis, H. leiopelta*, and *H. leiopelta armata*) are restricted to the Kamchatkan district, and two of these to the area between Kamchatka and Japan. Turning to the west coast of North America we find a different state of affairs.

1. Twenty-one species do not extend north of San Francisco Bay, as follows:

Astropecten californicus.[a]
Astropecten ornatissimus.
Dipsacaster eximius.
Dytaster gilberti.
Luidia asthenosoma.
Luidia ludwigi.
Myonotus intermedius.
Pectinaster a. evoplus.
Odontaster crassus.
Pseudarchaster pusillus.
Ceramaster leptoceramus.
Hippasteria californica.
Cryptopeltaster lepidonotus.
Poraniopsis inflata.
Henricia l. dyscrita.
Henricia polyacantha.
Henricia clarki.
Solaster exiguus.
Pteraster trigonodon.
Pteraster coscinopeplus.
Pteraster t. arcuatus.

2. The following southern Californian forms extend their range to Washington (*) and southern Alaska (†) but not north of Sitka:

*Thrissacanthias penicillatus.**
*Dipsacaster anoplus.**
Luidia foliolata.†
Asterina miniata.†
*Henricia l. annectens.**
*Heterozonias alternatus.**
*Pteraster jordani.**

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[a] To Bodega Head, just north of San Francisco Bay.

3. Ten Californian species are of still wider range, extending to the vicinity of Kadiak Island (*) or to Bering Sea (†). Solaster borealis ranges to Japan. They are as follows:

*Nearchaster aciculosus.**
*Mediaster æqualis.**
Ceramaster clarki.†
*Hippasteria spinosa.**
Henricia leviuscula.†
Henricia aspera.†
Henricia asthenactis.†
Solaster borealis.†
Peribolaster biserialis.†
Hymenaster perissonotus.†

4. Three other Californian species which range little if any south of Monterey Bay extend to Sitka (*) or the Asiatic region (†), as follows:

Leptychaster anomalus.†
*Dermasterias imbricata.**
Solaster dawsoni.†

In the above lists there are thirty-three species which do not reach the coast of Asia and are distinctive West American forms.

Considering the more northern forms, there are twenty-eight species which do not reach California, and of these twenty do not extend their range to the Asiatic coast or outlying islands, making with the above thirty-three species, fifty-three characteristic west coast forms, not found on the Asiatic side.

5. Of the twenty-eight species which do not range south of Oregon, nine are confined to the region of the Aleutians and Bering Sea, two of them ranging as far west as the Commander Islands (*), as follows:

Dipsacaster borealis.
Nearchaster pedicellaris.
*Ceramaster arcticus.**
Cladaster validus.
Henricia longispina aleutica.
Solaster hypothrissus.
*Pteraster marsippus.**
Pteraster temnochiton.
Hymenaster kœhleri.

6. The remaining nineteen species are found in the region between Kamchatka and Oregon, but those marked with an asterisk (*) are wide ranging forms which reach Japan. Those marked ** reach Bering Sea, and those indicated with a † extend to the Asiatic coast or outlying islands.

*Leptychaster pacificus.***
Dipsacaster lætmophilus.
*Benthopecten claviger.***
Benthopecten mutabilis.
Luidiaster dawsoni.†
*Nearchaster variabilis.***
Gephyreaster swifti.
Pseudarchaster parelii alascensis.
*Pseudarchaster dissonus.***
*Ceramaster japonicus.**
Hippasteria heathi.
Henricia spiculifera.
Henricia longispina.
Henricia leviuscula multispina.†
Solaster stimpsoni.†
*Solaster paxillatus.**
Pteraster multispinus.
Pteraster gracilis.
Pteraster tesselatus.†

Even making liberal allowance for our meager knowledge of the region, it will be evident that the coast of Asia north of Japan is much poorer in peculiar species than the northwest coast of America, the former possessing four and the latter over fifty characteristic forms.

It has been stated above that 76 per cent of the Phanerozonia and Spinulosa are indigenous to the North Pacific. It remains to point out that of the intrusions 12 per cent are derived from circumpolar species, while about 12 per cent come from the south, even as far as the extremity of South America, and that the shallow water southern forms do not push so far north as the deeper water species. The case with the circumpolar species is somewhat similar, for the forms which range the farthest south are inhabitants of deep water.

The derivation of the indigenous species, or rather of their ancestors, is too clouded with uncertainty to admit of exact treatment. It may be suggested, however, without greatly overstepping the bounds of ascertained fact, that these forms probably came from the same sources as the species not peculiar to the region, namely, from the Arctic Ocean, from middle and South America, and to a slighter extent from the direction of Japan. There remain, however, a number of forms whose nearest relative outside the region can not be ascertained.

SYSTEMATIC DISCUSSION OF THE FAUNA.

Class ASTEROIDEA Burmeister.

Free echinoderms with radially disposed gonads; with the ambulacral appendages, which are each connected with a double or single ampulla, confined to an open ventral ambulacral furrow and regularly arranged in two or four rows; radial ambulacral water tubes and radial nerves exterior to ambulacral ossicles and not covered by any plates; digestive system radiate and extending into the rays; respiration by means of dermal gills or papulæ; madreporic aperture abactinal; anal aperture usually present.

KEY TO THE ORDERS OF ASTEROIDEA.

a^1. Marginal plates usually large and conspicuous, defining the contour of body; abactinal skeleton in the form of paxilliform plates,[a] or flat, tessellate plates which are smooth or armed with granules or spines, and either naked or covered with thin or thick membrane. Pedicellariæ never pedunculate forcipiform, but spiniform, pectinate, valvate, or excavate. Papulæ restricted to abactinal area (except in some Linckiidæ and Asteropidæ) circumscribed by the marginal plates. Mouth plates prominent; ambulacral plates well spaced; tube feet in two series; rays usually 5 normally (except in some *Luidia*) .... *Phanerozonia* Sladen, p. 17.

a^2. Marginal plates not usually conspicuously large; abactinal skeleton not composed of true paxilliform plates, nor in the form of a tessellated pavement, but usually more or less reticulate or imbricated. Papulæ frequently but not invariably also intramarginal and actinal. Some form of abactinal spinulation always present; tube feet with well-developed sucking disks.

  b^1. Actinostomial ring with adambulacral plates prominent; pedicellariæ very rare, never pedunculate forcipiform nor excavate; ambulacral ossicles not crowded; abactinal skeleton composed of thin, close-set overlapping plates, or forming a more or less open reticulate network, either regular or irregular; plates often cruciform with or without connecting independent ossicles. *Spinulosa* Perrier, p. 251.

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[a] The abactinal skeleton when paxilliform may be joined by definite and regular intermediate ossicles, but is never irregularly reticulate; compare Solasteridæ, which bear pseudopaxillæ.

b^2. Pedicellariæ pedunculate, either forcipiform or forficiform (crossed or straight); actinostome with ambulacral plates prominent except in Brisingidæ. Skeletal plates bearing spines, often long and isolated, on or about which are usually grouped the pedicellariæ; or the pedicellariæ may be isolated; marginal plates inconspicuous or aborted; ambulacral plates often very crowded with tube feet in four series. Abactinal skeleton formed of skeletal arches (transverse on rays) independent or bound together by intermediate plates, forming a network with rectangular or very irregular meshes. These skeletal arches correspond to every other or to every third adambulacral, and are composed of pieces corresponding in the ventral, lateral, and dorsal regions of the body. Mouth plates usually inconspicuous.......................... *Forcipulata* Perrier.

Order PHANEROZONIA Sladen, 1889.

=Paxillosa+Valvata (Valvulata) Perrier, 1881, 1894,+Notomyota Ludwig, 1910.

With the characters given above.

KEY TO THE KNOWN FAMILIES OF PHANEROZONIA.

a^1. Tube feet pointed without a definite flat sucking disk, but sometimes with a small pointed knob at tip.

b^1. Ampullæ single, one to each tube foot. No intestine, no intestinal cœcum, no anal pore. Marginal plates thin and lamelliform. Cribriform organs between the marginal plates. *Porcellanasteridæ*, p. 22.

c^1. No actinal fascioles; cribriform organs localized in interradial arcs; no superambulacral plates; paxillæ or simple embryonic abactinal plates with a few spicular spinelets. *Porcellanasterinæ*, p. 23.

c^2. Actinal fascioles; cribiform organs of a simple nature and between all the marginals; superambulacral plates present; paxillæ.................................. *Ctenodiscinæ*, p. 31.

b^2. Ampullæ double; simple cribriform organs, or more or less specialized marginal fascioles usually present; abactinal plates always paxilliform; superambulacral plates always present.

c^1. Superomarginal plates replaced by paxillæ; broad inferomarginals; no anus, no intestinal cœcum, no intestine; compound papulæ................................ *Luidiidæ*, p. 105

c^2. Superomarginals never aborted, though sometimes small; not replaced by paxillæ similar to those of dorsum; intestine present; cœcum only exceptionally absent (*Blakiaster*); anal pore usually present, frequently of minute size, and sometimes absent; papulæ simple.

d^1. Marginal, adambulacral, and actinal plates bordered by a single row of spinelets united by a web-like membrane, forming specialized fascioles identical with cribriform organs; marginals and actinals usually covered with thin membrane; actinals in double or single interradial series, between which are the specialized fascioles leading from marginal fascioles to adambulacrals; adambulacral armature simple usually in a single marginal series; paxillæ with marginal spinelets webbed............................... *Goniopectinidæ*.

d^2. Marginal and actinal plates never bordered by a single row of webbed spinelets, nor are spinelets of paxillæ webbed; superomarginals variable; inferomarginals always massive; marginals never overlaid by a smooth membrane; actinal plates never in double interradial series, with each double series separated by specialized fascioles; actinal plates with paxilliform groups of spines or spinelets; adambulacral armature always in several series, intergrading into actinal spinelets.. *Astropectinidæ*, p. 37.

a^2. Tube feet with well-developed sucking disks.

b^1. Abactinal plates paxilliform or tabulate with groups of coordinated granules or spinelets; or in the form of spinopaxillæ; or simple and flattened with few spinelets (in the latter case the marginals are alternate and very spiny).

c^1. Marginal plates appreciably alternate and with sharp conspicuous spines; a pair of muscle bands extending along dorsal wall of each ray, from region of third to eighth ambulacral ossicle to tip; papulæ usually confined to base of ray and adjacent portion of disk, often to a localized papular organ..*Benthopectinidæ*, p. 120.

c^2. Marginal plates opposite (at least at base of ray) and not conspicuously spiny; no dorsal muscle bands; papulæ not confined to base of ray and adjacent portion of disk and never localized in a special papular organ.

d^1. One or two conspicuous recurved hyaline teeth to each pair of mouth plates; an odd interradial marginal .... *Odontasteridæ*, p. 153.

d^2. No conspicuous recurved hyaline teeth; odd interradial marginal present in one genus.

e^1. Spinelets of tabulate paxilliform plates very slender and glassy; marginal plates small, not much larger than adjacent actinal plates; odd marginal present; actinal interradial areas small; tabulate abactinal plates with internal radiating ossicles; calcareous interbrachial septa; ampullæ single .... *Chætasteridæ*.[a]

e^2. Spinelets not slender and glassy; no odd interradial marginal; abactinal plates tabulate or paxilliform; ampullæ double.

f^1. Abactinal plates tabulate, paxilliform, arranged in oblique transverse rows on either side of a conspicuous medioradial series and with special internal imbricating ridges; actinal intermediate plates aborted or very few; interbrachial septa calcareous; gonads extending far along rays; general facies astropectinoid .... *Archasteridæ*.[b]

f^2. Abactinal plates tabulate, often paxilliform, not arranged in definite oblique series; no internal imbricating ridges; actinal interradial areas large, with numerous plates; interbrachial septa usually membranous; gonads interradial......... *Goniasteridæ*, p. 158.

b^2. Abactinal plates are neither tabulate nor paxilliform, but are flat, convex, spinous, tubercular, granulous, or smooth; are sometimes overlaid by a thin or thick, smooth or granulous, skin; marginal plates with or without robust spines or tubercles.

c^1. Disk large; actinal interradial areas extensive, but no papulæ on actinal surface.

d^1. Marginal plates large, conspicuous; abactinal skeleton composed of polygonal, circular, or stellate plates united into a firm pavement; with or without secondary abactinal intermediate plates; plates may be smooth, granulous, spiny, tubercular, or covered by a smooth or granulous skin; papulæ single, or a few to an area, not numerous and in circumscribed areas; interbrachial septa usually membranous...................... *Goniasteridæ*, p. 158.

d^2. Marginal plates large but as a rule inconspicuous, being more or less hidden by granulous skin or encroachments of papular areas; abactinal skeleton stellato-reticulate; plates always granulous; papulæ numerous, and in definite areas; abactinal plates usually with large conical tubercles or spines. Disk usually high, or body thick and cushion-like; interbrachial septa usually calcareous .... *Oreasteridæ*.

d^3. Marginal plates small, more or less imbricated and whole body covered by thick, smooth, tough skin; abactinal skeleton tessellate or reticulate, the plates loosely imbricated; prominent spines exceptional, small spines present in some genera......... *Asteropidæ*, p. 247.

c^2. Disk small, with very small actinal interradial areas as a rule (if at all well developed, then papulæ on actinal surface); marginals small; skeleton tessellate; tegumentary developments granulate (skeleton overlaid by a smooth skin, without prominent spines in *Leiaster*) *Linckiidæ*, p. 240.

CHARACTERS USED IN THE CLASSIFICATION OF PHANEROZONIA.

In dividing an order into families, one endeavors to use only those characters which are of more than generic value yet which are not wide enough in scope to be of use in subdividing the class, that is, are not of ordinal importance. In determining the order Phanerozonia the ambital skeleton and distribution of the respiratory papulæ are used, although in the transitional or intermediate family Linckiidæ these characters are variable, which is tantamount to saying that the order is not sharply defined. This is indeed the case.

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[a] The classification of *Chætaster* presents unusual difficulties owing to the intermediate nature of the genus. It does not appear to belong in the Linckiidæ, nor in any other family. Ludwig created the Chætasteridæ as a provisional group. The presence of an odd interradial marginal, and in one species of rudimentary recurved teeth suggests *Odontaster*, but unlike that genus and its allies, the interbrachial septa of *Chætaster* are calcified, and the ampullæ single. In some respects the genus shows a remote alliance with the Ganeriidæ.

[b] The old and well-known genus *Archaster* is an isolated and remarkable type, for, though superficially resembling *Astropecten*, it is really near the *Goniasteridæ*. It has heavily calcified interbrachial septa, no superambulacral ossicles, tabulate abactinal plates, those of the regular oblique transverse series imbricating by curious internal keels, produced toward the midradial line. The very regular and enlarged radial series of plates and the readily recognizable primary apical plates recall the Goniasteridæ. The ampullæ are strongly double, and the tube feet have heavy sucking disks.

A study of the majority of genera in the Phanerozonia has led me to rearrange somewhat Verrill's revision of Sladen's classification, especially as regards the Astropectinidæ. The characters used in determining the families are emphasized in the key. These relate to the water vascular system, to the modifications of the abactinal skeleton, to the structure of the alimentary canal, to the modifications of the marginal plates, and structure of actinal intermediate plates. The pedicellariæ are not used, except in connection with several primary characters. They are suggestive for determining the relationships of species and genera, but are unreliable for any higher groups in this order. The superambulacral plates are important when taken in connection with other characters; their absence is often an important character in determining kinship. The gonads are chiefly of use in determining relationship of species. Their arrangement is apparently constant within a genus, but can not be used for families.

Not all the primary characters are of use for every family, and such characters as the form of the tube feet and abactinal plates are common to several families. They might better be called superfamily or subordinal features. Thus the order may be divided into two groups, those with pointed tube feet (no definite sucking disk being present) and those in which the tube feet have a definite sucking disk. The first group nearly coincides with Perrier's Paxillosa, and includes the families Porcellanasteridæ, Goniopectinidæ, Astropectinidæ, Luidiidæ. The first family is sharply marked off by the possession of only a single ampulla to each tube foot; the other three have two. The first family also has a peculiar modification of the marginal plates, in the form of cribriform organs,[a] and differs from all the others except the Luidiidæ in lacking an intestine and intestinal cœcum. The Luidiidæ are separated from the Goniopectinidæ and Astropectinidæ by the structure of the alimentary canal just referred to, and by the abortion of the superomarginal plates. The Goniopectinidæ constitute an aberrant type near the Astropectinidæ, from which they differ in having simple marginal cribriform organs as well as webbed fascioles between the actinal intermediate plates. The family is not large, and holds an intermediate position between the Porcellanasteridæ and Astropectinidæ. But the segregation of the group from the Astropectinidæ is desirable, as it leaves the latter much more homogeneous. The Astropectinidæ include all genera with pointed tube feet, double ampullæ, intestine, superambulacral plates, and true paxillæ (or the readily derived parapaxillæ). The presence or absence of an anus does not figure, as this character is worthless, for it varies within a genus. Thus the family includes *Plutonaster* and its allies, classified by Sladen, Perrier, Ludwig, Kœhler, Gregory, MacBride, and their followers in the Archasteridæ, and by Verrill in a distinct family (which can not be diagnosed), the Plutonasteridæ.

Before considering the second group, that characterized by having tube feet with suckers, a word concerning the pointed tube feet is necessary. Several authors have stated that the pointed tube feet are directly related to the habit of living on a muddy bottom, and have in a way discredited the character for classificatory purposes. This may be true, but paxillæ, which leave arcade-like spaces for the circulation of water about the papulæ, are just as directly related to the same habit, as also are the various sorts of fasciolar channels between the marginal and actinal intermediate plates, and the still more specialized cribriform organs of the Porcellanasteridæ. Unless climbing, a starfish does not move by attaching its suckers to the bottom and drawing itself along, as is sometimes stated, but it rests on the tips of the tube feet,[a] which are manipulated like a centipede's legs. Consequently a starfish with suckers can walk or crawl on muddy bottom, and those with pointed tube feet can crawl on hard bottom, as they do. For example, *Leptychaster*, *Persephonaster* (*Psilasteropsis*), *Astropecten*, *Ctenophoraster*, *Patagiaster*, *Luidia*, *Ctenodiscus*, and some other genera with pointed tube feet frequently occur on hard sandy bottom, on gravel, on sand, coralline, and shells, or on mixed coral and coral sand and shells. Similarly, members of the following families with suckers on the tube feet live on soft mud, and, for aught we know, have for ages. If the tube feet changed readily it is curious we do not find some of these families having genera with pointed tube feet. Benthopectinidæ, Chætasteridæ, Odontasteridæ, Archasteridæ Goniasteridæ (all subfamilies), Oreasteridæ, Asteropidæ, Linckiidæ, and practically every family of the Spinulosa and Forcipulata (Cryptozonia). There are more species, with suckers, living on globigerina ooze than there are with pointed tube feet (for comparison see Sladen, 1889, p. 713). I think it is evident that the pointed tube feet constitute a conservative and deep-seated character.

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[a] Present also in the Goniopectinidæ, although always of a simple type.

Since the pointed tube feet are of superfamily importance, it follows that Sladen's Archasteridæ, still used by most writers, is an unnatural group, as it contains both types of structure. The family can not be diagnosed in a rational manner. When the heterogeneous elements composing it are partitioned in other groups where they belong, nothing is left but the genus *Archaster*, which is an aberrant type of uncertain relationships. As Verrill has already indicated, the family should be retained for this genus only.

The reasons for enlarging the Astropectinidæ are discussed under that family.

The families having well-developed sucking disks to the tube feet are as follows: Benthopectinidæ (Pararchasterinæ of the Archasteridæ Sladen), Archasteridæ (restricted), Odontasteridæ (part of Pentagonasteridæ Sladen, and Archasteridæ Perrier), Chætasteridæ (part of Linckiidæ, most authors except Ludwig), Goniasteridæ (including Antheneidæ), Oreasteridæ, Asteropidæ, and Linckiidæ. The Benthopectinidæ are readily separated on account of their more or less alternate very spiny marginals, dorsal muscle bands, long slender rays, restricted papular areas, rudimentary paxillæ, and the characteristic form of the pedicellariæ when present. They possess a combination of characters not duplicated even in part in any other family. Ludwig has recently raised this group to ordinal rank (Notomyota). The Odontasteridæ, Chætasteridæ, and Archasteridæ are small families. The first and perhaps also the last are related to the Goniasteridæ. The Chætasteridæ are extremely puzzling. I have placed them in the key next to the Odontasteridæ, but the group is difficult to classify. The glassy spinelets are duplicated elsewhere only in the Spinulosa, but the structure of the abactinal tabulate plates, the marginals, and the presence of superambulacral plates, favor the Phanerozonia. The single ampullæ are noteworthy. They are double in the families mentioned above. As throwing some light on the relationship of *Chætaster* with the Odontasteridæ, the odd interradial marginal is important, and the presence, in the recently described *Chætaster vestitus* Kœhler, of incipient recurved specialized teeth to each pair of mouth plates. These spines have an enlarged opaque base and a hyaline tip.[a]

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[a] See Jennings: Behavior of *Asterias forreri*.

With the Goniasteridæ a transition between the paxilliform, or tabulate abactinal plate, and the flat granulate or smooth type takes place. It would be desirable, if it were possible, to divide the Goniasteridæ into two families, one with tabulate more or less paxilliform abactinals, and the other with flat pavement-like plates, either with or without secondary intermediate connecting ossicles of various sizes. The practical difficulties in the way of such a course are discussed under the Goniasteridæ. The diagnosis of the Goniasteridæ as it now stands is rather too general, and perhaps vague. The reason for this is the persistence from past ages of many intermediate intergrading forms. Naturally if there is anything to evolution, these intergrading forms should be expected. (If they all persisted, it is evident that there would be no definable orders, families, genera, or species.) The Oreasteridæ are not very sharply separated from the Goniasteridæ, but after the removal of *Amphiaster* the group is more homogeneous, and is readily recognized by the stellato-reticulate abactinal skeleton, large papular areas, with numerous small papular pores, and the finely granular skin which hides the underlying plates. The Goniasteridæ, on the other hand, have single papulæ, or a very limited number to an area, and abactinal plates tessellate, or in a close network through the presence of small intermediate plates. The transition between the typical tessellate form and the more open structure such as occurs in *Hippasteria* and *Anthenea* is too complete to keep these genera, which are not very closely related, in a separate family. They are nearer *Goniaster* than are *Pseudarchaster*, *Mimaster*, or *Gephyreaster*. The Asteropidæ are also difficult to diagnose satisfactorily, although the component genera differ from the Goniasteridæ in having small imbricated marginals, and a variable, loose abactinal skeleton overlaid by thick skin. The Linckiidæ (omitting *Chætaster*) have come to be more or less traditional. The phanerozoniate characters are rather unstable, especially the papulæ. Some of its genera are near the Goniasteridæ.

As already stated, Ludwig has raised the Benthopectinidæ, which he divides into two families, to ordinal rank. The character upon which greatest emphasis is laid is the presence of a pair of muscle bands extending along the cœlomic surface of the dorsal wall of the ray, from near the base to the tip. These are not present in any other group. The alternate marginals are correlated with the muscles, as greater flexibility is given to the ray. Ludwig believes the animals can swim by flexion of the rays, and this idea is incorporated in the name of my new genus, *Nearchaster*. The pectinate pedicellariæ of several genera are also peculiar to the group.

In this report I have kept the ordinal groups somewhat larger than an acceptance of the Notomyota would permit, although it is possible the Forcipulata are coördinate with the Notomyota. However, the orders of Asteroidea are even less satisfactory than the families, and they will ever furnish an excellent bone of contention. If the Notomyota is accepted, the Phanerozonia will become a superorder. This will necessitate the creation of a new order for the Porcellanasteridæ, and a rearrangement of Perrier's Paxillosa and Valvata. Perhaps some investigators will find the following scheme acceptable:

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[a] Kœhler, An account of the Shallow-water Asteroidea, Echinoderma of the Indian Museum, pt. 4, June, 1910, pl. 19, fig. 11.

Phanerozonia. Marginal plates prominent; papulæ confined to abactinal area circumscribed by the marginal plates.

1. Order Cribellosa, new. Tube feet pointed, without sucking disk and with single ampullæ; cribriform organs; no intestine.

Family Porcellanasteridæ.

2. Order Paxillosa Perrier, emended. Tube feet pointed, with double ampullæ; abactinal plates paxilliform; superambulacral plates; intestine present or absent.

Family Goniopectinidæ.
Family Astropectinidæ.
Family Luidiidæ.

3. Order Notomyota Ludwig. Tube feet with sucking disks; a pair of dorsal muscle bands present in rays; marginal plates alternate and spiny; pectinate pedicellariæ; abactinal skeleton, reduced paxillæ, or flat plates.

Family Benthopectinidæ.

4. Order Valvata Perrier. Tube feet with sucking disks, and without other characters of Notomyota; abactinal plates varying from paxilliform to flat tessellate; pedicellariæ bivalved, excavate, foraminate.

Family Archasteridæ.
Family Chætasteridæ.
Family Odontasteridæ.
Family Goniasteridæ.
Family Oreasteridæ.
Family Linckiidæ.
Family Asteropidæ.

Family PORCELLANASTERIDÆ Sladen, 1889.

Phanerozonia with relatively thin and lamelliform (not block shaped) marginal plates, which are naked or covered with rather thick membrane. Abactinal area with simple perforated embryonic plates, some of which bear a spinelet, or with paxilliform plates. A central conical prominence on abactinal surface. Actinal interradial areas more or less extensive, paved with squamiform intermediate plates, covered with delicate membrane, and sometimes bearing isolated spinelets or fimbriated channels. Cribriform organs present. Adambulacral plates large, with a simple marginal armature, uniserially disposed. Superambulacral plates present in one genus; no anus; no intestine; no intestinal cœca. Tube feet pointed; ampullæ single.

KEY TO THE KNOWN GENERA OF PORCELLANASTERIDÆ.

- a^1. Cribriform organs highly developed, localized; actinal interradial areas without fimbriated transverse channels; no superambulacral plates.
  - b^1. Both inferomarginals and superomarginals present.
    - c^1. Actinal intermediate plates usually but not always naked; adambulacral plates with a single series of spines on furrow margin only; terminal plates large, armed with conspicuous spines; cribriform organs one to eleven.
      - d^1. With a conical apical elongation; abactinal membrane with simple spiniferous spicules; actinal intermediate plates not imbricated; ambulacral furrows wide and exposed; rays more or less turned back; cribriform organs one to three.
        - e^1. Component structure of cribriform organs lamelliform.
          - f^1. One cribriform organ .... *Porcellanaster*[a] W. Thomson.
          - f^2. Three cribriform organs .... *Eremicaster* Fisher, p. 23.
        - e^2. Component structure of cribriform organs papilliform; one cribriform organ. *Sidonaster* Kœhler.
      - d^2. No conical apical elongation of abactinal integument, but a slight peak may be present; abactinal membrane with pseudopaxillæ; actinal intermediate plates imbricated and arranged in columns; ambulacral furrows narrow and concealed; rays not revertible; cribriform organs five to eleven (three in one case only); component structure papilliform.
        - e^1. Superomarginal plates with robust spines forming a single series along the median line; marginal plates united along median line of the rays.
          - f^1. Spines of adambulacral armature long and needle shaped, radiating apart; cribriform organs three to seven in each interradius; no ventrolateral plates in ray; actinal areas not granulated .... *Styracaster* Sladen.
          - f^2. Adambulacral spinelets spatulate, united by membrane into a scoop-shaped group; cribriform organs eleven; a single series of ventrolateral plates to tip of ray; actinal areas granulated .... *Chunaster* Ludwig.
        - e^2. No spines on superomarginal plates; spines of adambulacral armature short, compressed, forming independent series or fans .... *Hyphalaster* Sladen.
    - c^2. Actinal intermediate areas covered with spiniform granules. Adambulacral plates with papilliform spinelets on the outer portion of plates; terminal plate very small and inconspicuous, unarmed; cribriform organs fourteen .... *Thoracaster*[b] Sladen.
  - b^2. Inferomarginal plates aborted; one cribriform organ .... *Albatrossaster* Ludwig.
- a^2. Actinal fasicioles or fimbriated channels present; cribriform organs of a simple nature and between all the marginals; small superambulacral plates (in *Ctenodiscus*).
  - b^1. An unpaired superomarginal and inferomarginal in each interbrachial arc and a corresponding unpaired double series of actinal intermediate plates .... *Pectinidiscus* Ludwig.
  - b^2. No odd interradial marginal; no unpaired double series of actinal intermediate plates corresponding thereto .... *Ctenodiscus* Müller and Troschel, p. 31.

Subfamily PORCELLANASTERINÆ Sladen, 1883.

Porcellanasteridæ with cribriform organs highly developed, localized. Actinal interradial areas with squamiform plates covered with a simple membrane, and not traversed by fimbriated channels; no superambulacral plates.

Genus EREMICASTER (Fisher.)

Eremicaster (subgenus of *Porcellanaster*) Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 293. Type, *P. tenebrarius* Fisher.

Eremicaster Ludwig, Zool. Anz., vol. 31, 1907, p. 317. Type, *P. crassus* Sladen.—Fisher, Zool. Anz., vol. 32, 1907, p. 14.

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[a] Includes *Caulaster* Perrier; see Ludwig, Zool. Anz., vol. 31, 1907, p. 318, footnote.

[b] Includes *Pseudaster* Perrier; see Ludwig, Zool. Anz., vol. 31, 1907, p. 313, footnote.

Diagnosis.—Like *Porcellanaster* Wyville Thomson, but with three (instead of one) cribriform organs in each interradius.

Marginal plates thin; superomarginals not united along the median line of ray and usually bearing a spine, these forming a series on each side of ray. Abactinal area covered with membrane containing very small, simple, perforated plates; those on disk bearing usually a single spinelet each; in center of disk a sort of prolongation of the integument forms a peduncle, containing an extension of the body cavity, but no intestine. Actinal interradial areas paved with thin plates, sometimes armed with spinelets. Adambulacral armature, one to three sharp spinelets. Usually "segmental pits and papillæ" are present. No superambulacral ossicles; tube feet conical, pointed. Ampullæ single.

Remarks.—When this group was described as a subgenus in 1905, I gave three characters, in order of importance, by which it could be distinguished from *Porcellanaster;* namely, three cribriform organs, presence of segmental pits and papillæ, and one or two adambulacral spinelets. Since then I have examined much more material, and have found that the last character is of no importance generically, while the segmental pits and papillæ are numerically variable. The absolutely constant character at all ages is the three cribriform organs. The segmental pits and papillæ are valuable when taken in connection with the three cribriform organs, as they show relationship. The second (aboral) spinelet of the adambulacral plates of *Porcellanaster* is homologous with the segmental papilla of *Eremicaster;* but the outer part of the ray in *Eremicaster* lacks the segmental papilla, and is therefore similar to *Porcellanaster*, except in those specimens in which three spinelets are present in addition to the segmental papilla or its homologue.

Ludwig has considered the segmental papillæ and pits as of primary importance.[a] He placed his *P. pacificus* which has three cribriform organs and no pits or papillæ in the restricted genus *Porcellanaster.* I have studied *pacificus* and consider it much more nearly related to *tenebrarius* than to *P. cæruleus.* Owing to the slight instability of the pits and papillæ in *tenebrarius* (includes *waltharii* Ludwig) it seems better to rely upon the cribriform organs as mentioned above. Therefore I have placed *pacificus* in *Eremicaster*, although Ludwig relegates it to *Porcellanaster.*

In raising my subgenus *Eremicaster* to a genus Ludwig changed the published type *tenebrarius* to *crassus* Sladen. This is contrary to a very elementary rule in nomenclature. *Eremicaster* will stand or fall with *tenebrarius* as type. As a matter of fact the two species are so close that it makes no material difference which is type, but the habit of ignoring well-established rules of nomenclature is a bad one.

EREMICASTER TENEBRARIUS (Fisher).

Pl. 1, figs. 1–4; pl. 2, fig. 4; pl. 53, figs. 4, 4*a*.

Porcellanaster (Eremicaster) tenebrarius Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 293.—Ludwig, Zool. Anz., vol. 31, 1907, p. 317.

Porcellanaster waltharii Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, July 17, 1905, p. 92, pl. 5, figs. 26, 27.

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[a] Zool. Anz., vol. 31, 1907, p. 317.

Eremicaster tenebrarius Ludwig, Zool. Anz., vol. 31, 1907, p. 318.—Fisher, Zool. Anz., vol. 32, 1907, p. 14.

Eremicaster waltharii Ludwig, Zool. Anz., vol. 31, 1907, p. 318.

Diagnosis.—Rays five. R = 38 mm.; r = 11 mm.; R = 3.45 r. Another specimen: R = 42 mm., r = 9 mm., R = 4.66 r. Breadth of ray at interradial line, 14 to 15 mm.; at outer edge of lateral cribriform organ, 9 mm.; height of "epiproctal cone," 3 to 5 mm. in different specimens. Related to *E. crassus* (Sladen). Rays elongated, stout fairly slender, abruptly tapering at base, but only very gradually on outer three-fourths; ambulacral furrows very wide. Superomarginals typically with one or two spinules on upper edge; inferomarginals unarmed, as many as nineteen in number; terminal plate with three to six spinelets; adambulacral plates with one or two spinelets (usually two in large examples), and one segmental papilla which is transformed into a spinelet distally on ray; mouth plates with two segmental papillæ, with one unpaired spine at inner angle and with one smaller spinelet at either side. Actinal interradial areas smooth; intermediate plates extending to fourth or fifth inferomarginal. Spinelets on abactinal membrane extending as far on ray as lateral cribriform organ; spinelets membrane-covered, terete, and spaced; abactinal area on ray very narrow.

Description.—The abactinal area is slightly sunken below level of the upper edge of superomarginal plates, and is narrow on rays; but it varies in width according as the marginal plates are arched inward. On outer two-thirds of ray it is often reduced to a mere line and is never wider than a neighboring superomarginal. Abactinal integument is thin but resistant, and on disk and basal portion of ray (as far as outer cribriform organ) is covered with simple, slender, spaced spinelets, which are sheathed in membrane so that they appear terete and truncate. They are slightly longer toward edge of disk. Beyond the outer cribriform organ no spinelets are present in the abactinal integument. On the central prolongation of the integument, or "epiproctal" cone, which is from 3 to 5 mm., the spinelets are minute, and when seen in connection with their simple, perforated, "embryonic" plates greatly resemble "tables," such as are present in the skin of many holothurians, the spinelet representing the spire. The abactinal plates are scattered on the ray, are closer on the disk, and crowded on the central prolongation or peduncle. They are, in form, small circular perforated plates, with a smooth or irregular contour, and do not differ materially from the perforated plates of many holothurians. Scattered among the spinelets (but not elsewhere) are numerous papulæ, especially in the interradial areas. They appear to be absent from the epiproctal cone.

The marginal plates always arch inward more or less so that when viewed from above the contour of body is usually defined by inferomarginals. Superomarginals (eighteen or nineteen in large specimens) are nearly quadrate and are larger than corresponding inferomarginals. They decrease regularly in size distally. Each plate bears, on its upper edge, one or two robust, tapering, sharp spinules, these forming a row to terminal plate. These spinelets are sometimes nearly as long as height of plate. A single spine stands at the top of the suture between the median and either lateral or cribriform organ. (For variations in presence of superomarginal spines, see *Variations* on p. 27.)

Terminal plate, seen from side, is about as long as last two superomarginals, and is strongly concave on side toward abactinal membrane. There are five, sometimes six, prominent spinules, subtubercular and conical; of these, one (rarely two) is on the extreme tip, one at either side of the end of ambulacral furrow just below the terminal spinule, and one on either side, abactinal in position. In Alaskan specimens there are only three spinules on terminal plate, those mentioned last being absent.

The inferomarginal plates are longer than high, and correspond to superomarginals in number; or there may be one more; they are not always exactly opposite plates of upper series. They do not extend onto actinal surface but are confined to side wall of ray. Inferomarginals lack spines or any special armature except the three cribriform organs shared with the superomarginals.

There are always three cribriform organs to each interbrachial arc. Of these the median is slightly the largest, having twenty to twenty-four lamellæ. These lamellæ are made up of a linear, perpendicular series of flat spinelets or oblong platelets in a thin web-like investment. More or less of the spinelets are free around the edges, especially the actinal. Each organ has a slight depression down the center.

Adambulacral plates are narrow and rather long, conspicuously excavated on furrow margin. Adoral end is most prominent and is surmounted by one or two sharp tapering spinelets, one slightly compressed and curved, being directed into the furrow; the other, usually a trifle smaller, is either reflected back over the plate or is turned aborad. The latter is frequently absent. Midway between the extremities of plate is a rather small valve-like, scoop-shaped scale, resembling one-half of a valvate pedicellaria—the "segmental papilla." It is articulated to plate, on edge of furrow by a straight base, and the free edge is broad and rounded. It closes over a small slit in the plate, which is absent beyond basal fourth of ray. The valve beyond the proximal third to two-thirds becomes transformed into a small lanceolate spinelet, so that there are either two or three spinelets to each plate beyond this point. Alaskan specimens, which are smaller than those from California, usually have only one regular spinelet, and the segmental papillæ extend rather farther along ray.

Mouth plates very prominent, the united pair forming a broad keel, with a wide lanceolate median suture, the companion plates touching at the inner and outer ends. The inner extremity of the combined pair is rounded and bears a single short, conical spinule (frequently absent from being rubbed off); and on margin, nearer peristome, on either side, is a curved compressed, smaller spinelet. Between latter and first adambulacral plate are two semicircular papillæ.

Actinal interradial areas small and triangular, without spinelets, and covered by a thin skin through which the plates are not discernible until specimen is partially or wholly dried. The plates are thin subcircular or elliptical, and not regularly arranged. In small specimens they are distinctly spaced. They extend as far as the edge of the fifth inferomarginal. Beyond this point there is a single row of what appear to be isolated intermediate plates, extending to tip of ray. These are the lower ends of the ambulacral ossicles, are triangular, the apex being adjacent to a suture between two adambulacral plates. At the tip of ray they are fairly conspicuous and three underlie the terminal plate. All these "plates" are invisible until specimen is dry. Between the flaring outer ends of companion mouth plates is a triangular unpaired plate, the exposed portion of the primary oral plate or odontophore.

Madreporic body large, adjacent to a median cribriform organ. It is about as wide as the latter. Striations deep and radiating.

Color in life: general tint whitish; bluish cast on disk due to viscera showing through integument.

Anatomical notes.—Superambulacral plates absent. Peristome contains small irregular perforated rods and plates especially on the lips. There are also a few simple straight and curved rods. Tube feet large, conical, without calcareous particles in walls. Ampullæ single, not double. The stomach is very simple, possessing very short radial pockets. The dorsal wall is closely bound to the abactinal body wall. There is no intestine and no anus, nor any sign of an intestinal cœcum. A prolongation of the cœlom fills the so-called "epiproctal" cone or dorsal peduncle, but the opening into the peduncle is closed by a layer of muscles. Gonads small, one on each side of the interradial septum.

Variations.—The specimens from California, six in number, present very few variations of importance. There is some difference in the width of the abactinal area on rays as explained above. Superomarginals range from fifteen to eighteen and there may be one to three superomarginal spines. There is sometimes but one adambulacral spinelet although there are usually two. The segmental papilla can be recognized as such on as many as fifteen adambulacral plates, and varies all the way to only five. It gradually is transformed into a lanceolate spinelet so that it is not easy to limit exactly the number.

Numerous smaller specimens from *Albatross* station 2859 vary more widely. R averages about 22 mm. and r 8 mm. ($R=2.75$ r). But one specimen has $R=22$ mm., $r=6$ mm., $R=3.6$ r, which is fully as long a ray as in the type. Superomarginal plates twelve to seventeen. Out of forty-five specimens from this station thirty-three lack entirely the superomarginal spinules, five have a spinelet here and there along the superomarginal series, and seven have a regular series of superomarginal spinules. These are lacking usually from the first two plates, and may be absent from an odd plate here and there. The marginal plates are a trifle smaller and weaker than in Californian examples. There is usually but one true furrow spinelet, which is curved and compressed. Rarely two are present, the second being placed directly behind the first. Segmental papillæ can be recognized as such for about one-half to three-fourths the length of furrow although the rudimentary pit is present only on the first four or five plates. The terminal plate has three instead of five spinelets.

The most important difference between these specimens and the Californian examples is the absence of superomarginal spinules in many of the former. Their presence in almost typical form in seven specimens shows however that superomarginal spinules are not wholly trustworthy as a specific character. The difference in the number of adambulacral spinelets is variable even in Californian examples. The difference in size may account for the more frequent presence of two spinelets in largest examples. The so-called "segmental papillæ" of the adambulacral plates are decidedly variable in the number to a ray and in degree of development. Size may also account for the presence of only three terminal plate spinules in Alaskan examples.

Although these Alaskan specimens present slight differences the totality of characters seems to warrant placing them under *tenebrarius*. The numerous specimens from the single station show greater variation among themselves than do the typical Alaskan and Californian examples, when compared.

Young.—The smallest specimen, from station 2859, has R = 10 mm., r = 5 mm., and eight superomarginal plates, one adambulacral spinelet, segmental papillæ, as such, only on two or three plates, after which they stand over furrow as broadly lanceolate flat spinelets; no superomarginal spinules. The cribriform organs are smaller than in the adult, with about ten lamellæ which tend to split up into individual spinelets, and the space between the cribriform organs is wider than in adult, about as in Sladen's figure of *E. gracilis.*[a] Abactinal spinelets are confined to the interradial areas, and in fact are scarce on the radial areas of the disk on many considerably larger specimens.

Type.—Cat. No. 22326, U.S.N.M.

Type-locality.—*Albatross* station 4397, about 200 miles off San Diego, California, 2,196 to 2,228 fathoms, on gray mud.

Distribution.—Southern Alaska to the Galapagos Islands, 1,569 to 2,259 fathoms.

Specimens examined.—Fifty-one specimens from the following stations:

2859, off Prince of Wales Island, southern Alaska, 1,569 fathoms, gray ooze, bottom temperature, 34°.9 F., forty-five specimens.

4394, off San Diego, California, 2,259 fathoms, soft gray mud, three specimens.

4397, about 200 miles off San Diego, California, 2,196 to 2,228 fathoms, gray mud, three specimens. Last two stations, *Albatross* cruise of 1904.

Remarks.—This species is closely related to *Eremicaster crassus* (Sladen), which was taken by the *Challenger* Expedition in 2,335 fathoms in the South Pacific, midway between Sydney and Valparaiso. From this form *tenebrarius* differs in having slenderer and (by comparison with figures) longer rays, and about twice as many marginal plates. *Eremicaster gracilis* (Sladen) from off the western coast of South America, between Valparaiso and Juan Fernandez, is probably only a very young specimen of *crassus* because the differences cited are such as would be expected in a young example. I have already pointed out how *tenebrarius* varies at one station in respect to the superomarginal spinules. It would have not been difficult to have created three species from this collection of forty-five specimens. Mention has already been made that in the young of *tenebrarius* abactinal spinelets are developed first on the interradial areas of disk. This would be equivalent to Sladen's phrase "abactinal membrane with spinelets confined to limited areas" and is borne out by his figure 1, on plate 20. The fact is, the species of this genus are more variable than commonly supposed.

After a careful comparison of specimens of *E. tenebrarius* with Ludwig's description and figures of *E. waltharii* from off Panama and the Galapagos Islands,

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[a] *Challenger* Asteroidea, pl. 22, fig. 3.

I am unable to find a single constant difference. The photographic figures of *waltharii* are just like *tenebrarius*. There are far greater differences between the extremes of Alaskan specimens than between typical *tenebrarius* and *waltharii*. Consequently I believe the latter to be a synonym of the former.

EREMICASTER PACIFICUS (Ludwig).

Pl. 2, figs. 1–3.

Porcellanaster pacificus Ludwig, Mem. Mus. Comp. Zoöl.. vol. 32, 1905, p. 89, pl. 6, figs. 28, 29; Zool. Anz., vol. 31, 1907, pp. 317, 318.

Eremicaster pacificus Fisher, Zool. Anz., vol. 32, 1907, p. 14.

Diagnosis.—Rays five. R=21 mm.; r=10 mm.; R=2.1 r. Breadth of ray at interradial line, 11 mm.; at outer end of lateral cribriform organ, 6.5 mm.; length of abactinal peduncle, 5 to 7 mm. Disk rather large and rays of median length; interbrachial arcs well rounded. Cribriform organs three; no segmental pits or papillæ; adambulacral plates with two sharp spinelets; marginal plates eight or nine, the superomarginals with one, rarely two, upright spinules; abactinal surface with spaced spinelets extending to outer cribriform organ; actinal intermediate areas with spaced spinelets.

Description.—Abactinal membrane capable of inflation. Disk and basal part of ray, as far as outer edge of lateral cribriform organ covered with spaced delicate, terete spinelets, each invested in a thin membrane. In one specimen the spinelets extend a short distance beyond cribriform organ. They are about 0.5 mm. high and spring from simple subcircular perforated plates embedded in the abactinal membrane. As a rule these plates have an irregular outline and are about one-half to two-thirds as broad as height of spinelet. The plates are more or less spaced and irregularly between them emerge the papulæ, singly. They have the appearance of being about as numerous as the spinelets. The central prolongation of the integument or peduncle contains crowded plates with rudimentary spinelets as in *tenebrarius*, and no papulæ. In the integument of ray beyond the limit of spinelets are simple subcircular perforated plates usually uneven or more or less toothed on margin; occasionally smooth. The plates are somewhat larger than those of disk, the largest being 0.6 mm. in diameter, a small one about 0.3 mm.; whereas on the spiniferous area at base of ray the largest are 0.35 to 0.4 mm., and are thicker in the center. The abactinal area varies in width on ray, even in same specimen, according as marginal plates are arched inward. Occasionally two or three isolated spinelets occur on outer part of ray.

Marginal plates in form about as in *E. tenebrarius*. Superomarginals eight or nine, each with an upright glassy tipped spinule on upper edge of plate, these about as high as plate when perfect and decreasing in size toward end of ray. Occasionally a second shorter spinule is present. Inferomarginals the same in number as superomarginals, confined to side wall of ray and longer than high.

Terminal plate fairly large, deeply concave toward abactinal area. There is one terminal spinule, and below at either side of end of furrow, one; behind terminal spinule on abactinal edge of plate a row of two to five spinelets on either side. In a small specimen from station 2859 these are lacking.

Cribriform organs large, always three. The median has about twenty-four lamellæ, the lateral about twenty. Their structure does not appear to be different from those of *tenebrarius,* although there is more tendency for the plate-like spinelets to remain independent.

Adambulacral plates shaped as in *tenebrarius* and with two acicular skin-covered spinelets on the margin. Of these one stands on the prominent adoral end of plate, the other a trifle shorter at about the middle of concave margin or a little nearer adoral end. The longest spinelet is about as long as plate; the other is the homologue of the segmental papilla of *E. crassus* and *E. tenebrarius.*

Mouth plates very prominent actinally, a little wider at outer end than in *tenebrarius.* Armature consists of an odd acicular spinule at inner end of combined pair and along the free margin a series of two to five similar spinelets increasing slightly in size toward first adambulacral.

Actinal interradial areas about as in *tenebrarius,* but covered with spaced skin-covered spinelets very similar in character and size to those of abactinal surface. These spinelets vary in length and are more numerous near the marginal plates than in the inner angle. Intermediate plates extend to fourth inferomarginal. At outer end of combined mouth plates the triangular end of the odontophore is visible. The triangular lower end of ambulacral ossicles is visible, as in *tenebrarius,* between the inferomarginal and adambulacral plates, forming a series extending to tip of ray.

Madreporic body large, about as wide as median cribriform organ to which it is adjacent.

Anatomical notes.—No superambulacral plates. Gonads interradial. Stomach simple with two short pouches protruding into base of arm. No intestine; no anus. There are no deposits in peristome, in the specimen examined.

Type.—Will be deposited in U. S. National Museum.

Type-locality.—Exact locality not stated; description based on specimens from seven stations between lat. 14° 46′ N. and lat. 0° 36′ S., and long. 98° 40′ W.; region of the Gulf of Panama.

Distribution.—Bering Sea (south of Pribilof Islands) to Gulf of Panama and vicinity of Galapagos Islands, 859 to 1,879 fathoms, soft mud and ooze and fine sand.

Specimens examined.—Six from the following stations:

2859, off Prince of Wales Island, Alaska, 1,569 fathoms, gray ooze, two specimens.

3075, off Washington, 859 fathoms, green mud, one specimen.

3603, Bering Sea, between Pribilof and Umnak Islands, 1,771 fathoms, brown ooze, three specimens.

Remarks.—The specimens agree well with Ludwig's description and figures of his *Porcellanaster pacificus,* which thus, like *tenebrarius,* has a wide distribution. There are a few minor points of difference, as in the spinulation of the terminal plate, but this is subject to variation. The nearly related *vicinus* is insecurely separated from *pacificus.* Among the differences mentioned by Ludwig the only one of any importance is the absence of actinal interradial spinelets.

As mentioned under the generic description it seems better to place this species under *Eremicaster* than with *Porcellanaster*, the segmental papillæ being subject to individual variation, while so far as known there is no variation in the number of cribriform organs.

Subfamily CTENODISCINÆ Sladen, 1889.

"Porcellanasteridæ with a simplified form of cribriform organ on the margins of each pair of marginal plates. Actinal interradial areas traversed by fimbriated channels, in continuation of the fasciolar or cribriform channels between the marginal plates" (Sladen). Superambulacral plates present, though not well developed.

Genus CTENODISCUS Müller and Troschel.

Ctenodiscus Müller and Troschel, System der Asteriden, 1842, p. 76. Type, *Asterias polaris* Sabine=*A. crispata* Retzius.

Anodiscus Perrier, Ann. sci. nat., sér. 5, vol. 12, 1869, p. 298.

Diagnosis.—General form stellato-pentagonal to stellate; abactinal surface with true paxillæ; marginal plates thicker than in typical Porcellanasteridæ; marginal, actinal intermediate, and adambulacral plates obscured by a continuous skin; marginals bearing each a short spine at upper end of plate, these forming two longitudinal series along ray; cribriform organs in the form of fasciolar grooves between marginal plates, these grooves continued as simple channels (roofed by webbed spinelets) across actinal intermediate area and between adambulacral plates; adambulacral plates with three to five furrow spinelets. No anus. Superambulacral plates present.

CTENODISCUS CRISPATUS (Retzius).

Pl. 3, figs. 1–4; pl. 4, figs. 1–6.

Asterias crispata Retzius, Dissert. sistens species cognitas Asteriarum, 1805, p. 17.

Ctenodiscus crispatus Düben and Koren, K. Vetensk. Akad. Handl., 1844 (1846), p. 253.

Ctenodiscus australis (Lovén MS.) Lütken, Vid. Medd., 1871, p. 238.

Ctenodiscus krausei Ludwig, Echinodermen des Beringsmeeres, Zool. Jahrb., Syst., vol. 1, 1886, p. 293.

Ctenodiscus procurator Sladen, *Challenger* Asteroidea, 1889, p. 173, pl. 30, figs. 7–12. For numerous citations to 1899 see Ludwig, Fauna Arctica (Römer and Schaudinn, Jena) 1900, p. 450; also, Mem. Mus. Comp. Zoöl. vol. 32, 1905, p. 104, pl. 6, figs. 32, 33, for record in equatorial east Pacific.

Diagnosis.—Rays five, exceptionally four or six. $R = 1.66\ r$ to $3.16\ r$. General form stellato-pentagonal, to stellate, extremely variable. Abactinal surface more or less tumid and usually with an elevated cone in center of disk; paxillæ variable, usually low, with few to many spinelets which are short, clavate, and skin-covered. Marginal, actinal intermediate, and adambulacral plates obscured by a thin soft skin. Continuous narrow deep grooves extend between marginal plates, across intermediate area, and between consecutive adambulacral plates. These are overhung on either side by a fold of skin embedded in which are numerous flattened spinelets, as in the lamellæ of typical cribriform organs. Between special raised ridges of marginal plates these furrows are deeper and V-shaped with five to seven superimposed lamellæ on either side. Marginal plates eleven to twenty, in each series, from median interradial line to extremity of ray. A single short conical spine at upper end of each superomarginal, and another similar one on each inferomarginal on the actinolateral margin of ray. Adambulacral plates with an oblique series of three to five sharp short skin-covered spines, and on aboral outer corner a similar, usually shorter spine, covered with the general investment of actinal surface. Mouth plates prominent; along free margin, about six spines like those of adambulacral and at inner end of plate a single more prominent spine; two or three short conical tubercles usually stand in a series on either side of median suture, these sometimes as long as furrow spines. Superambulacral plates present.

Description.—No adequate description of this species is readily available. With the ample material at my disposal it seems well to give a description and at the same time to point out some of the most prominent of the variations. Instead of placing these last, a separate subhead is given to each category of characters and the variations considered at once.

This is a remarkably variable species, especially in the length of the rays, and their width, and in the general facies of the animal. Practically all of the most diverse variations may occur in examples from a single station, and they are thus not due to locality. As slender and broad armed forms occur among the smaller specimens this difference is not due to age.

Proportions.—A striking series of four nearly equal sized specimens from station 4235 illustrates admirably the difference in form, measurements being given in the accompanying table.

Measurements of Ctenodiscus crispatus.

Station.	R.	r.	R: r.	Number of superomarginal plates.[a]	Width of ray at base.[b]	Number of furrow spines.[c]	Width of madreporic plate.	Remarks.
4235^1	38	12.0	3.16:1	20	14	5	4.0	Actinal area very narrow; paxillæ medium sized.
4235^2	39	16.0	2.45:1	18	20	3-5	3.5	Paxillæ medium sized.
4235^3	36	14.0	2.57:1	16-18	18	3-4	4.0	Do.
4235^4	40	17.0	2.35:1	17-18	21	4-5	4.0	Paxillæ smaller.
4223^1	35	19.0	1. 8:1	13	23	3-5	3.0	Paxillæ medium sized; average proportion.
4223^2	33	18.5	1.84:1	11	22	4-5	2.5	Paxillæ larger (Pl. 4, fig. 5).
4286	29	17.5	1.66:1	12	20	3-4	2.75	Paxillæ small.

[a] From interradial line to tip of ray.
[b] Measured from one interradial line, across abactinal surface to adjacent interradial line.
[c] Spines on furrow edge of adambulacral plate; one or more spines on surface of plate not counted.

Specimen 4235^1 has slender, narrow rays (from above resembling a *Psilaster* somewhat) and numerous marginal plates with fairly wide fasciolar furrows. The intergradation is perfect, through 4235^4 to 4286, a very short-rayed form almost arcuately pentagonal, with few superomarginal plates. If, in the above table, the width of ray at base is compared with R, and the porportion R:r taken into account, the great difference in proportion is at once evident.

Abactinal surface; paxillæ.—In some specimens the epiproctal cone is *inverted*, in others very inconspicuous. In specimens with rays nearly the same length the width of the paxillar area varies considerably, especially at the end of ray, thereby giving some specimens a much more robust appearance. The fact that in some examples the abactinal wall is nearly plane, except for the epiproctal cone, and much inflated in others is due, of course, to the condition of the animal at the moment of death, but is important as magnifying one or two trivial characters, such as the angle of marginal plates and compactness of paxillæ. Two extremes, both from station 4223, will serve to illustrate variability of paxillæ. Each specimen has R = 34 mm.; in A, paxillæ in neighborhood of madreporic body have seven to twelve spinelets, occasionally as few as four on very small ones; of these never more than one is situated in center of tabulum and rather more than half the paxillæ have no central spinelet at all; in B the paxillæ ordinarily have from twelve to twenty-two spinelets, of which three to five occupy center of tabulum, and all or very nearly all have central spinelets, those paxillæ on outer part of ray having so few as one central spinelet.[a] When these two specimens are placed side by side the difference is very striking. Many of the specimens, both small and large, lack a central spinelet to paxillæ altogether, thus resembling exactly some Atlantic examples. There is as much if not more difference in the extremes of these specimens than is shown by Sladen's two figures illustrating paxillæ of *Ctenodiscus australis* and *C. procurator*,[b] while in the extremes of body-form the difference is greater than between figures 1 and 7, illustrating the same two species. I thought at first that the difference in size of madreporic body might furnish a character of some constancy, to separate *krausei* from *crispatus*, the latter having the larger body. This character also is very variable in Pacific specimens, some examples having fairly large, others small madreporic bodies. In four rather poorly preserved Atlantic specimens the madreporic body is more constant and is one and one-half times greater in diameter than in Pacific examples of the same size.

The shaft of the paxilla varies in length. In specimens from very deep water it is longer than in shallow water specimens.

The bases of paxillæ, or the abactinal "plates," are circular and rather closely placed, usually not quite touching. They are largest about one-half r from center of disk, decreasing in size toward tip of ray and center of disk. Along mid-radial line where there are no papulæ the plates are smaller and usually broadly elliptical. Papulæ are not regularly arranged, four to six usually occurring about a plate. They are single, and are lacking on a circular area in center of disk (including the central cone) and on five narrow radial and five narrow interradial areas extending from the center like the spokes of a wheel. On either side of the radial areas, papulæ extend to tip of ray.

Marginal plates.—Superomarginal plates exactly opposite inferomarginals. The former are thin and confined to side wall of ray. The actinolateral border of ray with its series of spines is slightly nearer upper than lower border of inferomarginals. The part of inferomarginal below the actinolateral spine has a rather broad specialized ridge, which is broader than intervening fasciolar furrow. This furrow is roofed over by a single row of spinelets immersed in a continuous web, eight or nine of these spinelets occurring between lower edge of plate and actinolateral spine. When dried the surface of plate shows often numerous minute bosses. Directly above the actinolateral spine the specialized ridge narrows abruptly and joins without a conspicuous break, that of superomarginal. The fasciolar channel is several times broader than the specialized ridge and is a V-shaped trough, on whose sides are five to seven parallel superimposed but distinctly spaced series of delicate spinelets in a continuous web. Each web extends from the upper end of a superomarginal plate to the actinolateral spine. The whole apparatus of five to seven webs or lamellæ on either side of the V-shaped trough, extending over its cavity, forms a very delicate cribriform organ or filter. The series of spinelets roofing the furrow are much flattened and the tip ends in several minute points. Owing to the greater width of furrow, these spinelets are much longer than those of lower end of inferomarginals. The other spinelets are narrow and more delicate and decrease in size in each successive tier toward bottom of furrow. In alcoholic specimens the membrane investing the spinelets is usually so thick that they are only seen with difficulty. The spinelets act only as a support for the membrane and do not themselves function as strainers, as in *Astropecten*. The superomarginal spine which stands at the top of the plate is either terete, tapering, and pointed, or broadly lanceolate and acute like a spear tip. On outer part of ray there are sometimes two spines on a few plates.

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[a] Atlantic specimens show the same range of variation.

[b] *Challenger* Asteroidea, pl. 30, figs. 4 and 9.

The variation in number of marginal plates has already been indicated in the table. The margin of ray and disk is thicker in some examples than in others, the appearance being heightened by recurved rays, when the actinolateral angle is rounder and less abrupt. The exposed surface of the specialized ridge of superomarginal plates is thin or narrow, but varies more or less, being slightly broader in four Atlantic specimens; but in another Atlantic example from off Newfoundland they are as narrow as in Alaskan specimens. The height of superomarginals is variable, specimens from 1,033 fathoms having much lower ones. This is readily appreciated by noting the distance between the two series of marginal spines in the interbrachial arc.

Actinal surface.—The adambulacral armature is essentially alike in both Atlantic and Pacific specimens, some examples showing a preponderance of three or four furrow spines, others of four and five. Besides the spine (not of furrow series) which usually stands on the outer aboral corner, there is usually one to several very much smaller and more delicate spinelets along adoral and outer edge of plate. These can not be distinguished readily unless specimen is dry.

Actinal interradial areas, like marginal and adambulacral plates, are overlaid by membrane through which the plates are scarcely visible until dried. Plates are arranged in series running from marginals to adambulacrals. Deep channels also follow same course. These are overhung by a series of spinelets embedded in membrane, being a continuation of the marginal fascioles. The interradial channel splits and runs on either side of mouth plates. The first on ray always runs between second and third adambulacral, the second between the third and fourth, and so on. The photographic figure will show the arrangement of plates.

Anatomical notes.—No intestine, no intestinal cœcum, no anus. The conical eminence in center of disk contains a prolongation of the cœlom and is divided by a vertical septum. Stomach large, single, firmly moored to abactinal wall. Hepatic cœca large, extending nearly to end of ray, and with spacious cavity. Gonads interradial, one on either side of the membranous interradial septum. Ampullæ single; tube feet large, conical, pointed; no deposits in walls; one Polian vesicle to each interradius.

Superambulacral plates present; absent from first and sometimes second ambulacral ossicle and also from last six or eight at end of ray. These plates are not very conspicuous, being dorsoventrally flattened and overlaid by membrane. Although Ludwig[a] states that they are absent from his specimens (Panama region), I think he must have overlooked them. They are very easily seen if a portion of the ray is treated with caustic potash solution. They are present in a specimen examined, from station 3307, from the great depth of 1,033 fathoms. I also dissected a specimen from station 2452, off Newfoundland, 89 fathoms, and the superambulacral ossicles are present.

In the center of the conical abactinal prolongation one can easily distinguish in many specimens a small "pore" evidently connecting with the body cavity. This is also present in many *Eremicaster tenebrarius*, and is what Sladen took to be an anus in *Porcellanaster.* I think it must be an artificial opening caused by a stretching of the abactinal membrane at the summit of the cone, and possibly subsequent wearing, as the rudimentary paxillæ are usually more or less worn down here.

The walls of the stomach contain numerous small straight or irregular rods and grains from 0.01 to 0.175 mm. in length. They are sometimes provided with irregularities on sides or are irregularly triradiate. They are found also in the walls of the hepatic cœca, but are not so numerous. On the lips of the peristome they are transformed into broader irregular flattened rods with a few perforations, but in the peristome itself are comparatively few scattered rods like those of stomach walls, and only near the lip are they perforated. In the wall of stomach near mouth the rods are usually simple and very regular, and tend to arrange themselves in close meridional series.

Japanese specimens.—I have eight specimens from station 4818, Sea of Japan, 225 fathoms. One of the largest of these is figured. All have very small low paxillæ with comparatively few spinelets. The superomarginals are also slightly narrower than in shallow-water Alaskan examples, but about as in specimens from 1,033 fathoms, Bering Sea. (The latter have large paxillæ, with usually high pedicels, which lack entirely the central spinelets.) The Japanese specimens have four, but occasionally also three and five furrow spines.

Another specimen from station 5039, south coast of Hokushu, 326 fathoms, is very different, having narrower and longer rays (R = 3 r), large paxillæ, with comparatively long pedicels, the summit of which lacks central spinelets, and small actinolateral spinules. There are four furrow spines, as in the Japan Sea examples. This is also figured.

Superambulacral plates are present.

Distribution.—Bering Sea, along the north coast of America to Melville Island; through Barrow Strait to Greenland; south along the east coast of North America to Cape Cod; west and north of Spitzbergen to latitude 80° 3′ N.; south to Faroe

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[a] Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 105.

Islands, and on the Norwegian coast from Kristiansund to Finmark; Spitzbergen, Barents Sea, Murman coast, Matochkin Strait, Nova Zembla, and northward; Kara Sea as far as longitude 79° E. From here to East Cape the species has not yet been recorded.[a] From Bering Sea the species ranges south into the Sea of Japan, and on the American side to California, and is recorded from the mouth of the Gulf of California (Ludwig) and Gulf of Panama (Ludwig), and under the name *procurator* from off the Chonos Archipelago, Chile, south to entrance of Smyth Channel (Sladen); off the east coast of southern South America as *australis* (Sladen).

Specimens examined.—About eight hundred and eighty-three.

Specimens of Ctenodiscus crispatus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2848	Near Shumagin Islands, Alaska	110	green mud	85	U. S. Nat. Mus.
2849	do	69	do	12	Do.
2852	do	58	black sand	45	Do.
2855	Off Sitkalidak Island, near Kadiak Island, Alaska.	69	green mud	14	Do.
2860	South end Queen Charlotte Islands	876	do	5	Do.
3075	Off Sea Lion Rock, Washington	859	do	3	Do.
3076	Off Washington	176	do	3	Do.
3077	Near Prince of Wales Island, southeastern Alaska.	322	do	58	Do.
3128	Off Monterey Bay, California	627	blue mud	1	Do.
3216	South of Alaska Peninsula	61	black sand, mud	66	Do.
3217	do	42	black gravel	1	Do.
3307	Bering Sea	1,033	green ooze	33	Do.
3494	do	65	green mud, fine sand	41	Do.
3530	do	59	dark green mud	16	Do.
3532	do	77	do	66	Do.
3538	do	59	green mud	4	Do.
3550	do	76	brown mud	104	Do.
3551	do	74	green mud	38	Do.
3552	do	54	black sand	2	Do.
3607	Bering Sea (north of Unalaska)	987	green mud, black lava sand.	156	Do.
3610	Bering Sea	75	green mud	([b])	Do.
	Alaska [c]			52	Do.
4194	Gulf of Georgia, British Columbia	111-170	soft green mud	1	*Albatross*, 1903.
4197	do	31-90		1	Do.
4223	Boca de Quadra, southeastern Alaska	48-57	soft green mud	21	Do.
4228	Near Naha Bay, Behm Canal, southeastern Alaska.	41-134	gravel and sponges	2	Do.
4229	do	198-256	soft gray mud	1	Do.
4231	do	113-82	green mud, fragments of slate.	2	Do.
4235	Near Yes Bay, Behm Canal, Alaska	130-181	gray mud, black specks	8	Do.
4246	Kasaan Bay, Prince of Wales Island, southern Alaska.	42-47	green mud	1	Do.
4271	Alitak Bay, Kadiak Island	35-41		1	Do.
4281	Chignik Bay	42-43	green mud	1	Do.
4286	do	57-63	green mud, rocks	1	Do.
4287	Uyak Bay, Kadiak Island	66-67	gray mud	2	Do.
4292	Shelikof Strait	102-94	blue mud	2	Do.
4768	Bowers Bank, Bering Sea	764	greenish brown mud	23	*Albatross*, 1906.
477[illegible]	do	584	green mud	11	Do.

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[a] The above is condensed from Ludwig, Fauna Arctica, vol. 1, p. 451, where authorities are cited.

[b] Many, all spoiled.

[c] Exact locality unknown.

Remarks.—Attention is again called to the marvelous variation exhibited by this species and to its very extended range. It is extremely doubtful if *Ctenodiscus australis* Lütken, 1871, from off the east coast of southern South America is a distinct species. The differences noted by Sladen are among the most variable characters. Compare the various figures of undoubted *crispatus* published herewith, and then the figures published by Sladen. It would not be difficult to make at least two species in Bering Sea and a third in the Sea of Japan with greater differences than seem to exist between "*australis*" and "*procurator*." Perrier [a] has already expressed the same doubt as to the difference between *australis* and European *crispatus*.

This starfish, judging by its wide distribution, seems well adapted to life on soft mud. The creatures are usually gorged with mud, from which they evidently derive their food materials.

Family ASTROPECTINIDÆ Gray, 1840, emended.

Astropectinidæ Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 180 (includes also Luidiidæ, *Henricia*, and *Solaster*).—Perrier, Révision des Stellérides, 1875, p. 329 (includes also *Chætaster*, Luidiidæ, *Archaster*, *Ctenodiscus*).—Viguier, Squelette des Stellérides, 1879, p. 225 (includes also *Ctenodiscus*, Luidiidæ).—Perrier, Mém. sur les Étoiles de Mer, etc., 1884, p. 266.—Sladen, *Challenger* Asteroidea, 1889, p. 174 (includes Luidiidæ and *Craspidaster* and omits *Plutonaster* and allies).—Verrill, Trans. Conn. Acad., vol. 10, 1899, pp. 201, 218 (omits *Plutonaster* and allies).

Phanerozonia with large marginal plates, true paxillæ, and parapaxillæ; with pointed tube feet (a flat or true sucking disk being always absent); with double ampullæ; no cribriform organs, but frequently well developed marginal fascioles which are never webbed; with an intestine and usually an intestinal cœcum; anus absent, small, or well developed; superambulacral plates always present.

Remarks.—This family is distinguished from the Porcellanasteridæ by the absence of cribriform organs, and in having double instead of single ampullæ; from the Goniopectinidæ in lacking webbed fascioles, and webbed paxillar spinelets; from the Luidiidæ in having an intestine, intestinal cœcum (as a rule), and superomarginal plates; from all other families in lacking a sucking disk to the tube feet.

The family Astropectinidæ as here limited includes the Astropectinidæ of Sladen less his Luidiinæ plus his Plutonasterinæ. It comprises Verrill's (1899) Astropectinidæ plus his Plutonasterinæ. I regret that it is necessary to emend Verrill's classification, which was a great improvement upon that of previous authors. A study of the genera involved, however, demonstrates that his Plutonasteridæ can not be maintained, for the group has just the weakness of the old Archasteridæ of Sladen and recent authors. The family can not be diagnosed with a requisite degree of precision to exclude the majority of Astropectinidæ and yet include the genera which he would desire to form the nucleus of the group. I have shown elsewhere that the Pontasterinæ of Verrill really belongs with the Benthopectinidæ. The Mimasterinæ have well-developed suckers on the tube feet and belong near the Pseudarchasterinæ.

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[a] Exp. sci. Cap Horn, 1891, pp. 143, 144.

Verrill included in his Plutonasteridæ three subfamilies, of which two have just been mentioned. The third, the Plutonasterinæ, I am unable to separate by any trenchant characters from the Astropectinidæ of Verrill (=Astropectininæ of Sladen). This was first brought strongly to my attention when working on the *Albatross* Hawaiian collections. The genus *Patagiaster*, according to Verrill's classification would go in the Plutonasterinæ, yet there is not a single character which separates it sharply from undoubted Astropectinidæ; the same is true of *Persephonaster, Thrissacanthias, Dipsacaster, Tethyaster, Plutonaster, Lonchotaster*, and the recently described *Ripaster*. Of course, even to-day the Astropectinidæ are supposed to differ from the Archasteridæ in lacking an anal aperture. An anal aperture exists in several undoubted Astropectinidæ (*Leptychaster, Psilaster, Persephonaster, Astropecten, Tritonaster*). No more unstable character can be conjured up to separate *Astropecten* and its near relatives from *Plutonaster, Dytaster*, or *Dipsacaster*. In the first place the absence or presence of an anus is difficult to determine in some species without sectioning. In the second place, there is good evidence that the character is variable within a genus (*Astropecten, Psilaster, Leptychaster*). At any rate, it is proved beyond peradventure that typical Astropectinidæ may have an anal pore, sometimes of conspicuous size. Why not then let the "aproctuchous" myth take its proper place in history?

Verrill (1899, p. 199) has shown that the Archasteridæ is an untenable group as defined by Sladen. He has restricted the family to the genus *Archaster* Müller and Troschel. With this course I agree. As noted above, we differ on the disposition of *Pontaster* and the Plutonasterinæ. These are placed in the Plutonasteridæ by Verrill, the former being made the type of a subfamily. But in Verrill's diagnosis of the family (1899, p. 210) it is impossible to find any characteristic mentioned which is not shared by Astropectinidæ. In other words, the group is poorly defined and heterogeneous. After eliminating *Mimaster* and *Pontaster*, the remainder (that is, the Plutonasterinæ) is much more homogeneous, but the genera involved (*Plutonaster, Dytaster, Lonchotaster*) are connected with *Astropecten* by a very satisfactory series of intergrades. I have been unable even to make two subfamilies in the Astropectinidæ. If anyone wishes to try it, numerous possibly available characters are furnished in the accompanying table. Here all the genera are listed, and one may see how futile it is to attempt to separate *Plutonaster* and its allies, either in a family by themselves or as a part of that taxonomical catch-all, the Archasteridæ.

All genera here included agree in having pointed tube feet with double ampullæ, typical paxillæ (either the astropectinoid type or parapaxillæ), two series of marginal plates, an intestine, almost always an intestinal cœcum (one exception, *Blakiaster*), and always superambulacral plates. Their negative characters have already been mentioned after the diagnosis of the family. Minor characters of less than family importance are detailed in the accompanying table. So far as possible the order given to the genera is such that the Plutonasterinæ of Verrill would begin after *Tethyaster*, and probably would include *Persephonaster*, as this genus has been classified in the Archasteridæ, as also has *Psilaster*[a] by Ludwig, *Blakiaster* by Perrier (1884), and *Tethyaster* by Ludwig (1897) and Sladen (1889), although the last is exceedingly close to *Sideriaster*, which Verrill (1899) considers an undoubted astropectinid.

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[a] *Plutonaster abyssicola* Ludwig 1905 = *Psilaster pectinatus* (Fisher).

Table of genera of Astropectinidæ detailing their characters, but not including family characteristics. (The three marked with an asterisk have not been examined by the writer.)

Genus.	Paxillæ.	Parapaxillæ.	Abrupt narrow fascioles between marginals.	Fascioles not abrupt, or absent.	Anal pore small (×), or absent (××).	Anal aperature large.	Small actinal intermediate areas.	Odd interradial series of actinal plates.	Madreporite large, covered with paxillæ.	Gonads extending along ray.	The two series of marginals very unequal in size.	Adambulacral armature astropectinoid.	Adambulacral armature, a fairly straight furrow comb.
Leptychaster	×	×	×		× ××		×	×			×		(a)
Bathybiaster	×		×[b]		×		×					×	
Psilaster	×		×		×× ×		×						×
Blakiaster		×[c]		×	×		×	×					(a)
Astropecten	×		×		× ××		×				×[d]	×	
Ctenophoraster	×		×		××?		×	×			×	×	
Persephonaster	×	×		×	×	×	×						×
Tritonaster		×[e]		×	×		×				×	×	
*Moiraster**	×		×		(?)			(?)		(?)		×	
Sideriaster	×		×		×			(?)		(?)		×	
Tethyaster	×		×		×			×		×		×	
Thrissacanthias	×			×	×	×	×			×		(f)	
Dipsacaster	×		×			×		×	×	×			×
Patagiaster		×	×		×			×	×				×
Plutonaster		×	×[b]		×				×	×			×
Dy'aster	×	×		×	×		×		×	×			×
*Ripaster**		×		×	×					(?)			×
*Lonchotaster**		×	×[b]		×				×	(?)	×		×

[a] Furrow spines comparatively few, in an angular or curved comb intermediate between the two types.
[b] Shallow.
[c] Lobed, imbricating, convex plates simulating tabulate paxillæ (perhaps pseudopaxillæ).
[d] Not always.
[e] Also protopaxillæ.
[f] A special type, derived from the astropectinid.

KEY TO THE KNOWN GENERA OF ASTROPECTINIDÆ.

a^1. No specialized spines on either series of marginal plates; marginals armed with a uniform covering of small papilliform or squamiform spinelets.

b^1. Superomarginals smaller than inferomarginals.

c^1. Furrow margin of adambulacral plates angular, short, with a series of few long delicate spinelets. Madreporic body small, often partly hidden, but without special paxillæ on its surface; odd interradial actinal intermediate plates .... *Leptychaster*[a] Smith, p. 42.

c^2. Furrow margin of adambulacral plates gently curved, long (plate conspicuously longer than wide), bearing about 8 short spinelets. Madreporic body large, covered with special paxillæ; no odd interradial actinal intermediate plates................ *Lonchotaster*[b] Sladen.

b^2. Superomarginals not conspicuously smaller than inferomarginals; both series high, confined to side of ray; incipient marginal spinules in one superomarginal series, and two inferomarginal longitudinal series.. *Bathybiaster*[c] Danielssen and Koren.

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[a] Includes *Parastropecten* Ludwig and *Glyphaster* Verrill.

[b] Refers to *Lonchotaster forcipifer;* see sections a^2, b^2, c^2, d^2.

[c] *Bathybiaster robustus* frequently has the marginal spinules very small.

a^2. More or less conspicuous spines or spinules on inferomarginal plates, and also often on superomarginals as well.

b^1. Both series of marginals nearly equally developed, forming a more or less vertical lateral face to ray; at least, the superomarginals are not small and confined to abactinal surface of ray; the inferomarginals not forming lateral border to ray.

c^1. Inferomarginal plates touching adambulacrals throughout ray; not separated by a series of actinal intermediate plates, for a part, or the whole length of ray............*Astropecten* Gray, p. 55.

c^2. Inferomarginals separated from adambulacrals for a part or a whole of the ray by one or more series of actinal intermediate plates.

d^1. Superomarginal plates thick and block-like; at least not very thin and confined to side wall of ray.

e^1. Actinal interradial areas rather small and intermediate plates few (40 per cent or less of minor radius measured on dorsum; madreporic body never large and concealed by paxillæ; inferomarginals never defining ambitus).

f^1. Marginal plates not tumid, but with special elevations, there being narrow vertical rather shallow fascioles between the plates; actinal spinelets more or less sacculate.

g^1. Adambulacral armature forming a very angulated series on the furrow margin, the median spine considerably longer than the rest, and with a flap of integument at tip; all actinal spinelets very sacculate, and marginal spinules inconspicuous; abactinal paxillæ with stellate, imbricating bases.........*Bathybiaster* [a] Danielssen and Koren.

g^2. Adambulacral armature forming a curved series, the spinelets more numerous as a rule and central spinelet not enlarged nor bearing a conspicuous terminal flap; actinal spinelets frequently sacculate, and marginal spines or spinules conspicuous; abactinal paxillæ with subcircular or subpolygonal bases; not stellate..*Psilaster* Sladen, p. 71.

f^2. Marginal plates distinctly tumid, the fascioles between them obsolete; actinal spinelets not sacculate.

g^1. Gonads confined to interradial area of disk; not extending into arm; superomarginal spines present or absent; no enlarged actinal adambulacral spines.

h^1. Anal pore present; intestinal cœcum consisting of two bi- or trilobate sacs; a very narrow median radial area free from papulæ; adambulacral plates with gently curved furrow margin bearing numerous spinelets in a regular comb, and on actinal surface of plate several parallel rows of similar spinelets; abactinal paxillæ polygonal, independent; one or two, more or less, prominent superomarginal spines sometimes present; no odd interradial actinal intermediate plates.
Persephonaster [b] Alcock.

h^2. Anal pore probably present; no intestinal cœcum; a conspicuous median radial area free from papulæ; adambulacral plates with an angular furrow margin bearing five spinelets, and a few similar ones on actinal surface of plates as in *Leptychaster;* abactinal plates lobed, imbricating, with low convex tabula; no superomarginal spines; odd interradial actinal intermediate plates............*Blakiaster* [c] Perrier.

g^2. Gonads extending a short distance along dorsal wall of ray, on either side; prominent bristling superomarginal as well as inferomarginal spines; anus present and easily detected; one or two enlarged actinal adambulacral spines.
Thrissacanthias Fisher, p. 78.

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[a] Includes *Phoxaster* Sladen, and probably *Ilyaster* Danielssen and Koren. The latter has a long apical cone or funnel, and is evidently a very young individual.

[b] Includes *Psilasteropsis* Fisher.

[c] Near, if not identical with this genus, is *Bunodaster* Verrill, as yet not fully described. The type is *B. ritteri*, from "California." (See Verrill, American Naturalist, vol. 43, 1909, p. 554, fig. 4.) Professor Verrill has kindly sent me enlarged photographs of the abactinal and actinal surfaces of the type. The abactinal plates are in the form of low convex parapaxillæ, largest over central portion of disk. The general appearance of the creature is strikingly like *Blakiaster*, but I have no details of its anatomy. The actinal surface is identical with that of *Blakiaster*, even to the details of the actinal intermediate plates and the presence of the odd interradial actinals.

e^2. Actinal interradial areas fairly extensive with numerous intermediate plates arranged in definite series extending from adambulacrals to inferomarginals; (actinal intermediate plates occupying 50 per cent or more of minor radius, measured on dorsum, but marginals not greatly unlike in size, nor inferomarginals extending laterally beyond the superomarginals).

f^1. Madreporic body hidden by special paxillæ on its surface; inferomarginal plates and sometimes superomarginals with a single stout erect spine or spinule; abactinal paxillæ only slightly lobed, or polygonal, not markedly stellate. Adambulacral armature not astropectinoid; furrow spinelets in a regular comb.................*Platonaster* Sladen.

f^2. Madreporic body naked and large; adambulacral armature astropectinoid; abactinal plates stellate; marginal spinulation variable but not as above.

g^1. Inferomarginals with large flattened spatulate spinelets, chisel-shaped, roundish or square cut at tip, closely packed, with here and there a transverse row of five, but usually without order; actinal intermediate plates closely packed with stout flattened spatulate spinelets. Paxillæ with long pedicels and compact crowns of short inbending spinelets...*Moiraster*[a] Sladen.

g^2. Inferomarginals with a single transverse row of pointed spines in addition to much smaller papilliform or squamiform spinelets; actinal intermediate plates with clusters of papilliform or granuliform spinelets, separated by deep fascioles; paxillæ with only moderately long pedicels, sometimes short, the spinelets forming a distinct central group surrounded by a peripheral series; adambulacral plates separated by fasciolar grooves.

h^1. Gonads extending far along ray, on either side; a distinct medioradial series of paxillæ, slightly larger than two or three adjacent series (especially on outer part of ray); adambulacral fascioles shallow; deposits in tube feet; first adambulacral plate considerably compressed; central actinal adambulacral spinelets not increasing in length toward end of ray; madreporic body moderately large....*Tethyaster* Sladen.

h^2. [Gonads unknown]; no definite medioradial series of paxillæ slightly larger than those adjacent (?); adambulacral fascioles deep, densely lined with small delicate spinelets; stoutest actinal adambulacral spine increasing in size toward end of ray; madreporic body very large ....*Sideriaster*[b] Verrill.

d^2. Superomarginal plates thin and confined to side wall of ray; no fascioles between them.

e^1. Marginals with a single, rigid, sharp, perpendicular spine; madreporic body large with paxillæ on its surface ....*Dytaster*[c] Sladen, p. 101.

e^2. Marginal plates excessively thin and confined to side wall of ray, both series with a vertical series of five or more appressed flattened spines; madreporic body small, naked.
Ripaster Kœhler.

b^2. The two series of marginal plates unequal in size, often forming an angulated rather than vertical margin to ray; superomarginals much smaller than inferomarginals or at least confined wholly to abactinal surface on rays; inferomarginals often extending laterally beyond superomarginals, thus defining the border of rays (an exception in *Lonchotaster*).

c^1. Madreporic body not large and hidden by special paxillæ on its surface; anal aperature very small, or absent.

d^1. No well-developed series of plates between inferomarginal and adambulacral series throughout ray (rudimentary at base of ray in *Tritonaster*).

e^1. Superomarginal plates not conspicuously smaller beyond middle of ray. Marginal fascioles well developed...*Astropecten* Gray, p. 55.

e^2. Superomarginals very much reduced in size on outer part of ray; inferomarginals very tumid with an oblique series of long seta-like spines; no marginal fascioles... *Tritonaster* Fisher.

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[a] Sladen, *Challenger* Asteroidea, 1889. p. 192. Type, *Archaster magnificus* Bell, Ann. and Mag. Nat. Hist., ser. 5, vol. 8, 1881, p. 440; see Kœhler, Trans. Roy. Soc. Edinburgh, vol. 46, 1908, pt. 3, p. 630, pl. 12, figs. 107-110.

[b] Verrill, Trans. Conn. Acad., vol. 10, 1899, p. 219. Type *S. grandis* Verrill. The genus is very closely related to *Tethyaster*.

[c] Includes *Crenaster* Perrier, not d'Orbigny.

d^2. A single well-developed series of actinal intermediate plates between inferomarginals and adambulacrals. Inferomarginals broad, short, and band like, their spines many and appressed to ray. Rays long, disk small .... *Ctenophoraster* Fisher.

c^2. Madreporic body large, hidden by paxillæ on its surface; anal aperature always present, large in *Dipsacaster*.

  d^1. Margin of ray defined by inferomarginals; superomarginals confined to abactinal surface on ray; deep marginal fasciolar grooves; actinal intermediate areas large; no pedicellariæ; paxillæ typical.

    e^1. Gonads disposed in a series along either side of abactinal integument of ray, extending beyond middle; papulæ distributed all over paxillar area....... *Dipsacaster* Alcock, p. 85.

    e^2. Gonads confined to interradial regions not extending into rays; papulæ absent from central portion of disk and a midradial band .... *Patagiaster* Fisher.

  d^2. Margin of ray defined by both series of marginal plates which are small and armed with a single small spine in addition to papilliform spinelets; marginal fascioles shallow; actinal interradial areas small, and intermediate plates not extending far along ray; actinal granuliform pedicellariæ and low abactinal paxillæ; closely related to *Dytaster*.
Lonchotaster [a] Sladen.

Genus LEPTYCHASTER[b] Smith.

Leptychaster SMITH, Ann. and Mag. Nat. Hist., ser. 4, vol. 17, 1876, p. 110. Type, *L. kerguelenensis* Smith.

Leptoptychaster SMITH, Philos. Trans., Roy. Soc., Zool. Kerguelen Island, vol. 168, 1879, p. 278. (Emended from *Leptychaster*.)

Parastropecten LUDWIG, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 76. Type, *P. inermis* Ludwig.

Glyphaster VERRILL, Amer. Nat., vol. 43, Sept., 1909, p. 553. Type, *Leptychaster anomalus* Fisher.

Diagnosis.—Rays normally five in number; abactinal surface flat or slightly arched by inflation of dorsal integument; actinal surface beveled on sides; disk variable in size, medium to small; rays typically of medium length, tapered; marginal plates entirely without specialized spines, the superomarginals typically very small, the inferomarginals short and band-like; deep fasciolar grooves between specialized transverse ridges of marginal plates, these grooves lined with close-set delicate spinelets; abactinal area covered with true paxillæ with subcircular to irregularly stellate bases on papular areas; crown of paxilla with numerous very small spinelets; papulæ absent from a circular area in center of disk and from a conspicuous median radial area (see *Dipsacaster*); actinal interradial areas small to medium sized, but much larger than in *Astropecten;* actinal intermediate plates low-paxilliform, imbricating; adambulacral armature, several longitudinal series of three to five spinelets; mouth plates with long furrow margin, and inner spines enlarged; ambulacral feet conical without a sucking disk; no pedicelleriæ; superambulacral plates present, though small; gonads interradial not extending along ray; anus absent or sometimes present.

KEY TO THE SPECIES OF LEPTYCHASTER HEREIN DESCRIBED.

a^1. Superomarginals small, forming a narrow margin to abactinal area; not conspicuously wider in interradial angle than at middle of ray.

  b^1. Inferomarginals placed very obliquely, their specialized ridges when cleared of spinelets only one-half width of intervening fascialar grooves at base of ray. Superomarginals paxilliform.
arcticus, p. 43.

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[a] Refers to *L. tartareus* in particular.

[b] All the evidence is against a typographical error, so the original spelling has been maintained in accordance with modern usage.

b^2. Inferomarginals more transversely placed, and less numerous; specialized ridge of each plate about as wide as adjacent furrow. Superomarginals, broader and not paxilliform; quadrate in shape. *propinquus*, p. 54.

a^2. Superomarginals larger, forming a conspicuous margin to abactinal area and wider and shorter in interradial angle than at middle of ray.

b^1. Stellate with sharp rays; abactinal plates decidedly stellate or lobed on papular areas; R.=2.3 to 3.1 r; inferomarginals (with spinelets) more than twice as wide as long; marginal plates twenty-two to thirty-five in adult specimens . . . . *pacificus*, p. 45.

b^2. Stellato-pentagonal, or stellate with short blunt rays; abactinal plates only obscurely lobed or stellate on papular areas; R.=1.6 to 2 r; inferomarginals on ray twice or less than twice as wide as long; marginal plates ten to eighteen in adults . . . . *anomalus*, p. 48.

LEPTYCHASTER ARCTICUS (Sars).

Pl. 8, fig. 1; pl. 9, fig. 4.

Astropecten arcticus M. SARS, Reise i Lofoten og Finmarken, Nyt Mag. f. Naturvidensk., vol. 6, 1851, p. 161; Fauna Litt. Norvegiæ, 1856, Heft. 2, p. 61, pl. 9, figs. 16–18; Översigt af Norges Echinodermer, 1861, p. 32.

Astropecten lütkeni BARRETT, Ann. and Mag. Nat. Hist., vol. 20, 1857, p. 45, pl. 4, figs. 3*a*, *b*, *c*.

Astropecten arcticus and *lütkeni* DUJARDIN and HUPÉ, Hist. nat. zoophytes Échinodermes, 1862, p. 428.

Archaster arcticus VERRILL, Amer. Journ. Sci. and Arts, ser. 3, vol. 16, 1878, p. 214.—STORM, K. Vidensk. Selskabs Skrifter, Throndhjem, vol. 8, 1878, p. 252.—PERRIER, Nouv. archives du mus. d'hist. nat., ser. 2, vol. 1, 1878, pp. 32, 88.

Leptoptychaster arcticus SLADEN, *Challenger* Asteroidea, 1889, p. 189.—LUDWIG, Fauna Arctica, vol. 1, 1900, p. 452.

Diagnosis.[a]—Rays five. R=32 mm.; r=10 mm.; R=3.2 r. Breadth of ray at base, 12 mm. (measured from interradial line). Disk medium-sized, rays tapering gradually to a blunt extremity; interbrachial areas rounded but rather abrupt; abactinal surface slightly inflated; sides of ray rounded; superomarginal plates small, resembling enlarged paxillæ, not markedly wider at base of ray than at middle or on outer third, forming a narrow margin to abactinal area; inferomarginals short, but fairly wide, placed very obliquely and forming the rounded edge to ray, most of the series being visible from above; no specialized spines on either series; adambulacral plates with a furrow series of three or four spinelets, and on actinal surface two or three longitudinal series (often irregular) of three to five spinelets each, with sometimes two or three small spinelets out of line; abactinal paxillæ very compactly placed, longest on interradial area of disk and on either side of median radial area along ray; actinal interradial areas fairly large, the intermediate plates extending far along the ray.

Description.—The paxillæ are closely placed and the difference in size between those of the midradial region of ray and center of disk, and those along side of paxillar area (particularly in the interradial region) is very marked—much more so than in *Leptychaster pacificus*. A large paxilla of the interradial region of disk presents a slightly convex crown of small terete, compactly placed spinelets, varying in number according to the size of the paxilla, a fairly large one having twenty to twenty-five peripheral and about the same number of central spinelets, a trifle shorter than column of paxilla. Papulæ absent from center of disk and along median radial area; five or six (sometimes four) about each plate irregularly, on interradial regions and along border of paxillar area of ray. Abactinal plates slightly and irregularly lobed on papular areas, much less obviously so than in *pacificus.*

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[a] From specimen taken at station 4792, in the vicinity of the Commander Islands.

Superomarginal plates, forty-one in number from interradial line to extremity of ray, are much smaller than in either of the two other species described below, and have the form of large paxillæ, being not conspicuously wider in interbrachial angle than midway along ray. They are irregular or subcircular in outline, rather straight sided adjacent to inferior series, have the appearance of being obliquely oriented, and do not correspond exactly to inferomarginals. Opposite the first ten superomarginals are seventeen abactinal paxillæ (or irregular transverse series). The superomarginals are confined to the abactinal surface and their spinelets are heavier and slightly more numerous than on the other paxillæ. Terminal plate wider than long, with a rounded end; notched adjacent to paxillæ.

Inferomarginals much shorter than wide, obliquely oriented (about 45°) to transverse axis of ray, and occupying entire side wall of ray. Each plate is therefore strongly arched, this arch giving the rounded margin. Each plate is covered with spinelets, stouter than those on superomarginals, somewhat squamiform on exposed surface, and very slender in the fasciolar grooves. These fasciolar grooves are deep, and about twice as wide *at base of ray* (taking transverse axis as length of plate) as the adjacent specialized ridge of the plate. The latter is a thin, almost laminar ridge, very much thinner than in *pacificus,* where the specialized ridge is as wide or wider than the grooves. Farther along ray in *arcticus* the ridges become thicker, nearly or quite as wide as grooves and the inferomarginals are more massive. A longitudinal shallow furrow separates the two series of plates.

Adambulacral plates with a curved furrow series of three or four rather long, slender, blunt, terete spinelets. Lateralmost spinelets slightly the shortest. On actinal surface of plate the spinelets decrease gradually in size outward, there being two or three longitudinal series of three or four spinelets, occasionally more. Sometimes a very few odd spinelets stand out of line. The first plate is wider than the rest, with more numerous spinelets.

Mouth plates narrow, the combined pair forming a salient angle into actinostome. Furrow margin long, with about ten spinules like those of adambulacral plates, decreasing in size outward, and continued along adambulacral margin in several smaller spinelets; innermost two spinules forming "teeth" at angle. An irregular series of spinelets smaller than furrow spinules stand along edge of median suture; and at outer end of plate are a few intermediate spinelets between the two series, which throughout the length of plate stand rather close together.

Actinal interradial areas fairly large, the plates being arranged in series between inferomarginals and adambulacrals. A single series of plates extends about half length of ray (from interradial angle); a second series, one-fourth; a third series, one-eighth or less. Between first superomarginal and first adambulacral are about six plates in an interradial direction.

Madreporic body nearer margin than center of disk; surrounded by six or seven large paxillæ which overhang the edges; ridges coarse, transverse rather than centrifugal.

Variations.—There are three specimens from station 3602 which are difficult to classify satisfactorily. Two resemble *arcticus* but have a larger disk, shorter and broader rays, and larger superomarginals. The third much resembles *anomalus*, and in the sum of its characters stands about midway between the two specimens, above referred to, and *anomalus*, which was taken at the same station. The aberrant specimens have inferomarginals resembling those of *arcticus*. R = 37 mm. (largest specimen); r = 15 mm.; R = 2.5 r. Breadth of ray at base, measured from interradial line, 18 mm. It is not improbable that this species hybridizes with *anomalus* whenever the ranges overlap, and that the very aberrant specimens may be explained by such a theory.

Type-locality.—Öxfjord, Finmark, 100 to 150 fathoms.

Distribution.—The distribution of this species is evidently circumpolar. In the Atlantic hemisphere it is found along the east coast of North America from lat. 38° to 45° N., and on the coast of Europe from south of Ireland, the Faroe Channel, off Norway from Trondhjem to Finmark, and eastward to Barents Sea and the Murman coast.[a] In the north Pacific region the species ranges over Bering Sea and south on the Asiatic side to Yezo, Japan.

Specimens examined.—One typical from station 4792, vicinity of Commander Islands, 72 fathoms, pebbles; two aberrant forms, 3602, vicinity Pribilof Islands, Bering Sea, 81 fathoms, green mud, sand; one from 5047, off Hokushu, Japan, 107 fathoms, dark gray sand, broken shells, pebbles.

Remarks.—The specimen from near the Commander Islands agrees in most particulars with an example from the coast of Maine (station 21, Cashes Ledge). The Atlantic specimen has the raised ridges of inferomarginals at base of ray, slightly wider.

LEPTYCHASTER PACIFICUS Fisher.

Pl. 8, fig. 2; pl. 9, fig. 2; pl. 50, figs. 1, 1*a*.

Leptychaster pacificus FISHER, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 112.

Diagnosis.—General form similar to that of *L. arcticus* (Sars). General form flattened; rays evenly tapered, bluntly pointed; interbrachial angle slightly rounded, but abrupt; abactinal surface subplane; margin of rays defined by inferomarginal plates, rounded; superomarginal plates well developed, relatively larger than in *L. arcticus*, forming a fairly conspicuous margin to abactinal paxillar area; actinal surface slightly convex; paxillæ compact, the larger with about twenty-five peripheral and thirty central spinelets; plates of papular areas lobed; papulæ in fives and sixes about each; adambulacral plates with four or five furrow spinules and on actinal surface two or three longitudinal series of about four similar spinules. Rays five. R = 43 mm.; r = 14 mm.; R = 3 r. Breadth of ray at base, 16 mm.

Description.—Abactinal paxillar area fairly compact, the paxillæ decreasing in size toward center of disk, midradial line, and end of ray; smallest paxillæ in center of disk, the largest on margin of area at base of ray. Paxillæ similar in character to those of *L. arcticus*, but slightly larger, and spinelets a trifle longer, Base of pedicel flaring into a roundish plate with four or five short, rather irregular. lobes by which the plates touch or imbricate slightly, and between which the papulæ emerge. Larger paxillæ with about twenty-five peripheral and thirty central slender delicate terete blunt spinelets; spinelets occupying center of tabulum form a coördinate flat-topped group, usually stand upright, and are crowded; peripheral spinelets usually radiate and are not equal in length.

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[a] Condensed from Ludwig, Fauna Arctica, vol. 1, p. 452.

Abactinal plates, in a prepared specimen, from inner or cœlomic side: Plates rather small and close-set irregularly stellate with short irregular lobes by which the plates overlap. Papulæ absent from a narrow radial line, interrupted on the interradial line, and absent from a circular area (with radius about 0.4 r) in center of disk. On the radial line the plates are more crowded, and are without regularity as to the number of lobes and in arrangement. The plates are also variable in size and more uneven in contour than those on the papular areas. The plates on the central nonpapular area of disk are small, roundish, and crowded, with a number of larger scalloped or irregularly incised plates scattered here and there. On the papular areas the plates are arranged in transverse rows parallel with interradial line, but the regularity is frequently interrupted. Adcentrally to the madreporic canal is a large tumid plate, rounded on the outer side and angular toward the canal. On either side are two smaller more elongate plates, while a small plate completes the circle on the outer side.

Marginal plates short, band-like, but both series more conspicuous than in *L. arcticus;* superomarginal plates, thirty in number, from interradial line to extremity of ray much wider than long on proximal half of ray, the width rapidly decreasing on outer portion until plates are nearly quadrate. Plates form an arched bevel to margin of abactinal area, are separated by deep fasciolar grooves, and are covered with short delicate terete spinelets, which form a close nap all over exposed surface.

Inferomarginals corresponding to superomarginals, beyond which they extend laterally, forming the rounded margin to ray. They are separated from superomarginals by a rather wide groove, which is not so deep as the transverse fasciolar furrows, these being deeper between inferomarginals than between superomarginals. Plates short, band-like, obliquely oriented to radial line (superomarginals being transversely oriented), forming a well-arched bevel to actinal surface. First plate about twice as wide as corresponding superomarginal (sometimes somewhat more). All plates densely covered with small spinelets similar to those of superomarginals, but a trifle larger, those of transverse median region slightly squamiform and directed outward.

Actinal interradial areas about the same size or a trifle smaller than in *L. arcticus;* one series of intermediate plates extending about three-fourths length of ray or to eighteenth inferomarginal; a second series extending to seventh or eighth plate, and a third series confined to angle bounded by adjacent first two plates. Intermediate plates with a low tabulum crowned by a coördinate group of fifteen or twenty papilliform spinelets, those in center being slightly thicker and more clavate than the peripheral ones.

Adambulacral plates about as wide as long, with a rounded furrow margin, but first two or three plates wider than long and with more angular margin. Armature consists of (1) a furrow series of four (more rarely five) slender, rather long, blunt cylindrical spinules, the two central being slightly the longest or the four subequal; (2) on actinal surface are two or three longitudinal series of about four similar spinules, which decrease in size toward outer edge of plate; third series when present more irregular, its spinelets distinctly tapered, slenderer, shorter, and sharper. Furrow spinelets usually bent back from furrow, and armature has a decidedly crowded appearance.

Mouth plates narrow, the free margin of each being longer than that adjacent to first adambulacral, and the combined plates forming a salient angle into actinostome. Margin of plate with a series of about 15 slender tapering spinules, decreasing in length from inner to outer end of plate. About eight to ten of these are more regular and occupy the free actinostomial margin, the rest being adjacent to first adambulacral plate, between which and the mouth plate there is a fairly wide suture furrow, and sometimes an incomplete, irregular, intermediate series is present.

Madreporic body situated about its own diameter from inner edge of superomarginal plates, fairly large, surrounded and partially obscured by large paxillæ; striations deep, coarse, irregular, centrifugal.

Superambulacral plates present, but small; one opposite each ambulacral plate except the first plate and a few at the very tip of ray.

Variations.—The variations exhibited by specimens of nearly equal size are slight. The relative dimensions, with the number of superomarginal plates, are listed below for several specimens:

Measurements of Leptychaster pacificus.

Station.	R.	r.	R:r.	Breadth of ray at base.	Number of superomarginals.
2862	24	9.0	2.6 :1	10.0	22
2862	40	14.0	2.92:1	16.0	26
3223	32	14.0	2.3 :1	16.0	24
4194	39	12.5	3.12:1	15.0	30
4198	23	7.5	3:1	9.0	27
2862	44	14.5	3:1	16.5	35

The paxillar area is slightly narrower in some examples than in others, and the relative amount of inflation of the abactinal integument also changes the external facies somewhat.

Young.—There are three small specimens which seem to be the young of this species; two from station 3223 have broader, more robust rays than a nearly equal-sized individual from 4194. The characters of the latter are as follows: R=9 mm.; R=4 mm.; R=2.25 r. Breadth of ray at base, 5 mm.; superomarginals, fifteen; paxillæ with three to five central and eight to ten peripheral spinelets; superomarginals inconspicuous; abactinal integument inflated; furrow spinelets four usually, the two central longest; actinal intermediate plates extending less than one-third length of ray measured from interradial angle; terminal plates conspicuous. One of the examples from station 3223 has the following characters: R=10 mm.;

$r = 5$ mm.; $R = 2r$; breadth of ray at base 6 mm.; superomarginals, fifteen; larger paxillæ about the same as in foregoing specimens, but spinelets shorter and area broader; furrow spinelets usually three; actinal intermediate plates extending more than one-third length of ray (nearly one-half); superomarginal plates more robust than in foregoing example; terminal plate conspicuous.

Type.—Cat. No. 21925, U.S.N.M.

Type-locality.—*Albatross* station 2862, near north end of Vancouver Island (inside) in 238 fathoms, on gray sand and pebbles.

Distribution.—Southern part of Bering Sea to Vancouver Island and from 56 fathoms in northern limit of range to 238 in the southern. Dwells on sand, pebbles, and soft mud.

Specimens examined.—Sixteen from the following stations:

Specimens of Leptychaster pacificus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number of specimens.	Collection.
		Fathoms.			
2856	Off Afognak Island, Alaska	68	shells	1	U. S. Nat. Mus.
2862	Vancouver Island, British Columbia (near north end, inside).	238	gray sand, pebbles	8	Do.
3223	Bering Sea, vicinity of Unalaska	56	black pebbles	3	Do.
3318	....do	61	black sand, gravel, shells	1	Do.
4194	Straits of Georgia, off Nanaimo, British Columbia.	111–170	soft green mud	2	*Albatross*, 1903.
4198	....do	157–230	....do	1	Do.

LEPTYCHASTER ANOMALUS Fisher.

Pl. 7, fig. 4; pl. 9, fig. 1; pl. 50, figs. 2, 2*a*.

Leptychaster anomalus Fisher, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 115.
Glyphaster anomalus Verrill, Amer. Nat., vol. 43, Sept., 1909, p. 554.

Diagnosis.—Rays five. $R = 27$ mm.; $r = 1.6$ r. Breadth of ray at base, 19 mm. Usual form stellato-pentagonal; disk broad, rays short, broad, and blunt; interbrachial arcs shallow and wide; general form depressed; abactinal surface subplane, capable of slight inflation; actinal surface slightly arched due to rays bending upward; marginal plates conspicuous, few in number, devoid of any enlarged spines or specialized armature, but covered with short spinelets; actinal intermediate areas broad; adambulacral plates with three or four furrow spinules, and on actinal surface with three longitudinal series of smaller spinelets, decreasing in length toward outer edge of plate; small superambulacral plates present; a very small anal pore present.

Description.—Abactinal paxillar area compact; paxillæ arranged in not very regular oblique transverse rows at sides of ray; without order in median radial area and center of disk. Paxillæ largest at base of ray and in interradial areas, decreasing conspicuously in size toward center of disk and tip of ray; larger at sides of paxillar area than in midradial region. Column of paxilla about as high as breadth of base, flaring at summit, the largest crowned with a coordinate floriform group of about forty or forty-five short, terete, often clavate, round-tipped spinelets; of these about one-half form a peripheral series and are a trifle slenderer and longer. On the smaller paxillæ the spinelets decrease markedly in size, but only slightly in number.

Abactinal plates in a prepared specimen, from inner or cœlomic side. Plates small, closer together along midradial line and in center of disk where there are no papulæ than at sides of area where papulæ are present. Plates of latter region are circular in general shape, but nearly always more or less irregular; with four, five, or six short, abrupt, lobes irregular in length, thickness and in distribution on the periphery of plate. These plates of papular area are arranged in perceptible, although irregular, oblique transverse rows (parallel with interradial line). Usually six papulæ occur around each plate (often five, and rarely four) emerging between the irregular lobes by which plates usually touch. Plates along median area of ray are even less regular than others, and frequently there are no lobes at all. They are slightly smaller, and papulæ are absent from a strip about four plates wide. Toward center of disk, plates decrease rapidly in size, become more crowded, and lobes if present are very inconspicuous and of irregular occurrence. The large primary interradial plate placed just adcentrally to the madreporic canal is convex internally (bears a large paxilla externally), and is slightly concave on the outer edge, next to madreporic canal; three or four other less regular and smaller plates complete the circle about the madreporic canal.

Superomarginal plates, fifteen in number from median interradial line to extremity of ray form an arched bevel to border of abactinal surface; plates shorter than wide, but increase in length on outer half of ray. Plates of both series separated by transverse narrow deep fasciolar grooves and a narrow deep groove from inferomarginal series. Superomarginal plates covered with short, terete, blunt, granuliform spinelets, similar to but larger than paxillar spinelets, becoming well defined, slender spinelets in the fasciolar grooves. The superomarginal spinelets are close-set and small, forming an even nap on the exposed surface of plates.

Inferomarginal plates much wider than long, encroaching more onto actinal area than do superomarginals onto abactinal, and corresponding in position to superomarginals. Spinelets, densely covering surface of plates, larger than those of superomarginals, and increasing in size toward outer end of plate which projects slightly beyond adjacent end of superomarginal, thus defining the ambitus. Inferomarginal spinelets somewhat granuliform in middle of plate, often attaining a squamiform appearance near outer end; spinelets in fasciolar furrows, slender. Spinelets on extreme upper or outer edge of plate (above the squamiform spinelets) are similar to those of adjacent portion of superomarginals, the true ambitus or edge of ray being a little below the margin of plate. It is on this rounded edge of ray that the largest spinelets occur. No enlarged spines or tubercles on either marginal series. Terminal plate small, granulose, deeply notched below.

Actinal interradial areas large; intermediate plates low-paxilliform, arranged in chevrons, the series adjacent to adambulacrals extending about three-fourths length of ray or to eighth inferomarginal. Plates decrease in size toward margin, are strongly imbricated internally, and the paxillar crowns which are composed of about twenty-five to thirty clavate obtuse, not very crowded, spinelets (slender when dry) surmount a very low convex elevation or tabulum. Well-defined fasciolar channels separate these tabula.

Adambulacral plates about as wide as long, with a slightly rounded, angular furrow margin, the angularity being more pronounced in vicinity of mouth plates. Armature consists of (1) a furrow series of four (sometimes three) terete or slightly flattened bluntly pointed tapering spinules about as long as plate and graduated in length orad, the longest spine being on aboral end of plate; or the spinules may be disposed like rays of fan and graduated in length toward either end of series. (2) On actinal surface are about three longitudinal series of smaller spinelets, decreasing in length toward outer edge of plate where the spinelets are like those of actinal intermediate plates. Four spinelets commonly occur in the inner actinal series and about three to five in each of the outer; or the two latter series may be wanting, the spinelets, instead, forming an irregular group, especially on outer part of ray where there are frequently upward to sixteen or twenty actinal spinelets.

Mouth plates narrow, rather prominent actinally, the free margins of the combined plates forming a salient angle into actinostome; free margin of each plate slightly angular near inner end and longer than the margin adjacent to first adambulacral. Armature consists of a furrow series of about six or seven tapering spinules decreasing in length from the inner enlarged tooth, outward, and thence continued along margin adjacent to first adambulacral in about nine much smaller spinelets similar to those of actinal intermediate plates. A superficial series of similar spinelets follows margin of median suture, increasing in size toward inner angle of plate, and an incomplete more or less irregular series often, but not always, occurs between marginal and superficial series. There is more or less variation in the details of dental armature. The exposed, outer, slightly convex surface of the combined plates has the appearance of being covered with a bristling armature of short papilliform spinelets, very similar to those on adjacent actinal intermediate plates.

Madreporic body rather large, about midway between center and extreme edge of disk. Striations coarse, centrifugal, very irregular; madreporic body sometimes nearly hidden by five or six large paxillæ.

Superambulacral plates present, though small. Absent from the first ambulacral plates, and from the distal six or seven, which are much reduced and crowded against the adjacent inferomarginals. Gonads forming a tuft of tubules on either side of the interradial septum, five or six tubules (two or three times dichotomously divided) to each tuft. The gonads do not consist of a series of tufts extending along the ray as in *Dipsacaster*. A Polian vesicle in each interradius. Interradial septa uncalcified.

Variations.—The specimens assembled under this form present a very considerable amount of variation, and when the extremes are placed side by side it is hard to believe that there are not two valid species. But there is such a bewildering number of more or less perfect intermediate stages that one is forced to range them all under one head.

The most important variations occurring in this species are in respect to dimensions and the size of the marginal plates. Some examples have a more stellate form, while others verge onto an arcuate pentagonal shape. Again, one extreme has fairly massive superomarginals, which are large up to the tip of the very blunt ray, while in the other extreme, the upper marginals are more numerous and relatively smaller, and the tip of the ray is not so blunt. The latter form is not so numerous as the first, which is "typical." The effect of this difference of shape on the relative dimensions is shown in the following table:

Table showing effect of shape on relative dimensions in Leptychaster anomalus.

Station.	R.	r.	R:r.	Breadth of ray at base.	Number of superomarginals.
3310	27	17	1.6:1	19.0	15
4281	21	13	1.62:1	16.0	10
3334	25	15	1.7:1	16.5	13
4281	29	17	1.7:1	19.0	13
3486	28	14	2:1	16.0	18

The number of spinelets on the outer half of the adambulacral plates (i. e., on actinal face) varies slightly, and they are a trifle longer and slenderer in some individuals than in others. The tip of the ray in this species is rounded and blunt, while it is sharp in *pacificus*. This, with the fewer and more transversely placed inferomarginal plates of *anomalus*, will serve to distinguish the longer rayed individuals from *pacificus*. Variation within narrow limits occurs in the size of the paxillæ, in general the examples with more massive marginals having the larger paxillæ. The greatest difference in general facies is caused, however, by the variation in size of marginals referred to above. A slight difference in width causes a varying amount of encroachment upon the abactinal paxillar area. In general the shorter armed individuals have wider and more massive marginal plates, but this is not invariably the case. The extreme variants in proportions are found at the same station.

Young.—The smallest specimen (station 4538) measures R=8 mm., r=6 mm.; rays broad, stout, blunt, with seven rather massive superomarginals, which are larger relatively than in adults. Paxillæ with nine or ten peripheral and two to five central spinelets; adambulacral plates with four furrow spines. Terminal plate small. This species has much larger marginal plates than equal sized *Pseudarchaster pusillus*, and the latter species has very large terminal plates and spiny inferomarginals, so that there is no danger of confusing the two forms in a superficial examination.

Type.—Cat. No. 21926, U.S.N.M.

Type-locality.—*Albatross* station 3310, vicinity of Unalaska, Alaska, 58 fathoms, on fine dark sand and mud.

Distribution.—Bering Sea (vicinity of Pribilof Islands and west of St. Paul) to southeast Alaska, and off Monterey Bay, California; on the Asiatic side to the Sea of Japan. Bathymetrical range, 32 to 688 fathoms in Bering Sea and northern part of range, to 871 fathoms off Monterey Bay. Found on fine gray or black sand, green mud, or on pebbles.

Specimens examined.—The following is a complete list of localities from which one hundred and seventy-eight specimens have been examined:

Specimens of Leptychaster anomalus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number of specimens.	Collection.
		Fathoms.			
2847	Vicinity of Shumagin Islands, Alaska	48	fine gray sand	1	U. S. Nat. Mus.
2848	do	110	green mud	13	Do.
2849	do	69	do	3	Do.
2852	do	58	black sand	2	Do.
2854	Off Kadiak Island, Alaska	60	do	1	Do.
2855	Off Sitkalidak Island, vicinity Kadiak Island, Alaska.	69	green mud	10	Do.
3223	Bering Sea, vicinity of Unalaska, Alaska.	56	black pebbles	1	Do.
3224	North of Unimak Island, Alaska	121	black sand and gravel	1	Do.
3257	do	81	gray sand and gravel	2	Do.
3263	do	61	black mud	12	Do.
3310	Vicinity of Unalaska, Alaska	58	fine dark sand and mud	15	Do.
3311	do	85	green mud	28	Do.
3313	do	68	fine black sand	50	Do.
3334	do	56	mud and sand	1	Do.
3486	West of St. Paul Island, Bering Sea	150	green mud, fine sand	2	Do.
3488	do	106	green mud, gray sand	5	Do.
3501	South of St. George Island, Bering Sea	688	green mud	1	Do.
3548	Near Unimak, Aleutians	91	black mud	1	Do.
3602	Bering Sea, vicinity of Pribilof Island	81	green mud, sand	1	Do.
	Shumagin Islands, Alaska	58		1	Do.
	Unalaska	80	sand	1	U. S. Nat. Mus., W. H. Dall, No. 6073.
	No locality [a]			9	U. S. Nat. Mus.
4230	Vicinity of Naha Bay, Behm Canal, southeastern Alaska.	240-108	rocky	3	*Albatross*, 1903.
4233	Vicinity of Yes Bay, Behm Canal	39-45	gray mud, rocky	1	Do.
4265	Off Sitka Sound, Alaska	[b] 590	green mud, rocky	1	Do.
4280	Chignik Bay, Kadiak Island	32	green mud, black sand	2	Do.
4286	do	57-63	green mud, rocks	2	Do.
4538	Off Monterey Bay, California	871-795	gray sand and rocks	1	*Albatross*, 1904.
4768	Bowers Bank, Bering Sea	764	greenish brown mud	3	*Albatross*, 1906.
4775	do	584	green mud	1	Do.
4784	Vicinity of Attu Island, Aleutians	135	coarse pebbles	1	Do.
4818	Sea of Japan (38° 08′ N.; 138° 31′ E.)	225	fine brown mud	1	Do.
4867	Sea of Japan	150	green mud	1	Do.

[a] Bottles broken by earthquake, 1906.

[b] Not typical.

Remarks.—The reasons which may be advanced for placing this species under the genus *Leptychaster* are the following: *Leptychaster arcticus*, which ranges into Bering Sea, has in the same region a close relative, *pacificus*, which differs in possessing broader and less numerous marginal plates. The superomarginals of *arcticus* are throughout the ray scarcely larger than paxillæ, but are of conspicuous size in *pacificus*, and in the interbrachial region are considerably wider than midway along ray. After a close comparison of the two forms it has not been possible to separate them generically. The character of the marginals, abactinal paxillæ, adambulacral plates and armature, distribution of gonads, and distribution of papulæ are essentially the same in the two forms. The width of the superomarginals remains the most conspicuous difference. By the same reasoning it is impossible to separate generically *anomalus* from *pacificus*. In the former the width of the superomarginals has been found to vary considerably; hence if this character is unstable for a species it obviously can not be used to diagnose a genus. The wholly unarmed marginals remain, however, very characteristic of the genus. Thus *L. arcticus* and *L. anomalus* represent two extremes, with *pacificus* in between. *L. propinquus*, described below, somewhat resembles *L. kerguelenensis* when viewed from above, and still more *Mimaster cognatus*, although the interbrachial arcs are rounder and the inferomarginals wider in proportion to length. As noted under *Gephyreaster swifti*, in view of the range of variation within the genus *Leptychaster*, it is very doubtful if *Mimaster cognatus* is a *Mimaster*. It seems to be a *Leptychaster*.

Leptychaster anomalus bears a striking resemblance to *Parastropecten inermis* Ludwig, which appears to be based on young specimens, however. From this species *anomalus* differs in having three or four furrow spinelets instead of six or seven, in having five or six papulæ about each plate or paxilla instead of four, and in having a minute anal opening.

The diagnosis given by Ludwig for *Parastropecten* is as follows:[a] Die neue Gattung unterscheidet sich von Astropecten durch den völligen Mangel von unteren und oberen Randstacheln, durch kurze Arme und durch verhaltnismässig grosse ventrale Interradialfelder, deren Platten (=Ventrolateralplatten) eine paxilläre Form haben. In other words, the genus is erected on the strength of the unarmed marginals and large actinal areas—just the features in which *Leptychaster* differs from *Astropecten*, for the size of the superomarginals has been shown to be variable within a species, and not diagnostic of the genus.

The impossibility of recognizing a separate genus *Parastropecten* for *inermis* and *anomalus* is the fact that *Leptychaster propinquus* would have to be ranked under *Leptychaster* on account of the small superomarginals, *L. anomalus*, of course, under *Parastropecten*, *L. pacificus* probably under *Parastropecten*, on account of the larger superomarginals, although it is obviously a close relative of *L. arcticus*. To divide the genera on the presence or absence of an anus would lead to the ranking of *Parastropecten inermis* and *Leptychaster arcticus* under one genus and the other forms under another, and would necessitate ignoring the very characters upon which we base genera.

Consequently, although *Parastropecten* seemed fully warranted when described, it seems best now to merge it with *Leptychaster*.

The genus *Glyphaster* Verrill based (without diagnosis) on *L. anomalus* seems to be synonymous with *Parastropecten*, which would therefore have precedence if *anomalus* constituted a separate genus. Since there are intergrading forms with *arcticus*, I have no hesitation in saying that neither *Glyphaster* nor *Parastropecten* can be so diagnosed as to include *Leptychaster propinquus* and exclude typical *Leptychaster*.

I have examined two small specimens from the Sea of Japan, collected by the *Albatross* in 1906. If the tiny specimen from off Monterey is certainly *anomalus*, the species probably has a continuous distribution by way of Bering Sea. It is of interest to note that the Japanese examples are fairly typical. Both of them have epiproctal cones, and in one the tiny anal pore is visible (in sunlight) with a strong glass.

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[a] Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 76.

LEPTYCHASTER PROPINQUUS Fisher.

Pl. 9, fig. 3.

Leptychaster propinquus Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 545.

Diagnosis.—Similar in general form to *L. anomalus*, but with narrower and more numerous marginal plates, less massive margin to disk, and smaller paxillæ. R = 29 mm.; r = 15 mm.; R = 1.93 r. Width of ray at base, 17.5 mm.

Description.—This form is obviously such a close relative of *anomalus* that the description will be largely a comparison with that species. Paxillæ arranged as in *anomalus*, but smaller and less compactly placed, and with longer spinelets. The paxillar area has the appearance of being more open and the outlines of the paxillæ are less well defined. While a large paxilla of *anomalus* has forty to forty-five spinelets, a similarly placed one in *propinquus* has but about twenty-five, the peripheral series containing about fifteen. The spinelets themselves are longer than in *anomalus*, especially the centrally situated ones. Distribution of papulæ and form of abactinal plates practically the same as in *anomalus*. Plates show a slight irregular lobing in some specimens; in others, none at all.

Superomarginal plates are nearly quadrate, except in interbrachial angle, where the width is slightly greater than length, and they are only one-half or slightly over one-half as wide as in equal sized specimens of *anomalus*, thus appearing more typical of the genus *Leptychaster*. The superomarginals are, moreover, more uniform in width throughout the ray than in *anomalus*. Superomarginals, twenty-one in number; in type of *anomalus*, which is practically equal sized, fifteen. Spinelets covering marginals similar to those of *anomalus*, but, as in the case of paxillæ, a trifle longer.

Inferomarginals shorter and narrower than in *anomalus*, corresponding in number and position to superomarginals, the covering being a trifle but not much longer than in *anomalus*. As compared with *arcticus* the inferomarginals encroach more onto actinal surface and are placed less obliquely to transverse axis or plane of ray. (The form bears no particular resemblance to *pacificus*, this species having large superomarginals.)

Adambulacral plates and spinulation not differing materially from *anomalus*. Furrow spinelets three or four, generally three; usually four in *anomalus*. The spinelets on actinal surface of plate are very similar if not identical in arrangement with those of *anomalus*, but are a trifle longer. Actinal interradial areas vary slightly in size and the paxillæ are a trifle smaller, and the spinelets slightly longer and slenderer than in *anomalus*. The mouth plates and armature do not differ in any important respect from those of *anomalus*.

Variations.—The essential features which distinguish this species are well marked in all of the fifty-seven specimens, and there is very little variation of consequence. In other words, all have small paxillæ and numerous and narrower marginal plates. The smaller specimens naturally have shorter rays, and there is a slight variation in the width of the superomarginals and inferomarginals.

Young.—The smallest specimen has R=7 mm., and is arcuate-pentagonal in shape. When compared with very young *anomalus*, the latter are seen to have fewer and much more massive marginal plates. The other differences between the adults are not so obvious but occur in a slight degree.

Type.—Cat. No. 24338, U.S.N.M.

Type-locality.—*Albatross* station 4792, vicinity of Commander Islands, Bering Sea, 72 fathoms, pebbles.

Distribution.—The plateau upon which the Commander Islands are situated. Bathymetrical range 54 to 72 fathoms.

Specimens examined.—Fifty-seven from three stations, all in the vicinity of Commander Islands: 4787, 54 fathoms, green sand, eleven specimens; 4788, 57 fathoms, green sand, forty-five specimens; 4792 (type-locality) one specimen. Taken by the steamer *Albatross*, June 14, 1906.

Remarks.—The only specimens among those assigned to *anomalus* which approach dangerously near the present species are six, which are unfortunately without locality. These have considerably narrower and more numerous superomarginals than typical examples, and more numerous inferomarginals, but there is no difficulty in distinguishing them at a glance from *propinquus*. When placed next to a series of the latter, their superomarginals are evidently much more conspicuous, especially in the interradial angle, while the inferomarginals are neither so numerous nor so short. Although the general form of the two is so nearly the same, the spinulation of the aberrant *anomalus* is typical, and not like that of *propinquus*.

I was at first inclined to regard this form as a race of *anomalus*, but in the absence of intergrades have classified it as a distinct species. It combines characteristics of typical *Leptychaster* and the synonymous genera *Parastropecten* and *Glyphaster*.

Genus ASTROPECTEN Gray.

Astropecten Gray (from Linck, 1733) Ann. and Mag. Nat. Hist., vol. 6, Nov., 1840, p. 180. Type *A. aurantiacus*, designated for the first time, 1908.—Fisher, Smiths. Misc. Coll., vol. 52, 1908, p. 93.

Stellaria Nardo, De Asteriis, Oken's Isis, 1834, p. 716. Type *S. aurantiaca*. Invalidated by *Stellaria* Møller.

Asterias Agassiz (not Linnæus), Mém. soc. sci. nat. Neuchâtel, vol. 1, 1835, p. 168.

Crenaster d'Orbigny, Prodrome de paléontologie, 1850, vol. 1, p. 240.

Diagnosis.—Rays normally five in number; abactinal surface flat, not arched; actinal surface slightly beveled on sides; disk variable in size, usually medium to small; rays usually long and tapered; marginal plates large, the inferomarginals always broader than superomarginals and sometimes extending laterally beyond them; inferomarginals armed with spinelets and a variable number of spines which increase in size toward the edge of ray; superomarginals, in addition to small granules or spinelets, may also bear tubercles or enlarged spines extending in one or two complete or interrupted rows along ray; or enlarged spines may be entirely absent; exposed surface of consecutive marginal plates separated by deep fasciolar grooves lined by minute capillary spinelets, these grooves acting as percolaters or filters; abactinal area covered with true paxillæ; papulæ single, usually absent from a narrower or wider midradial line, and from center of disk;

usually six about each paxilla; actinal interradial areas typically very small, with few paxilliform intermediate plates which do not extend far along ray, the inferomarginals and adambulacrals being in contact on the ray proper; intermediate plates never extend beyond middle of ray and rarely beyond proximal fourth; ambulacral plates with an angular furrow margin, bearing typically three spines, of which the middle is slightly the longer; two or three rows of spines on actinal surface of plates; first adambulacral plate compressed, much wider than the rest; mouth plates narrow, with inner spines enlarged; tube feet conical, without a true sucking disk; no true pedicellariæ; anus typically absent; gonads interradial, not extending along ray; superambulacral plates well developed.

KEY TO THE SPECIES OF ASTROPECTEN HEREIN DESCRIBED.

a^1. A more or less complete series of spines along upper edge of superomarginals, and frequently also a second parallel longitudinal series, spaced from the above; central granules of paxillæ usually considerably enlarged on disk; enlarged adambulacral spine usually abruptly truncate and often sulcate........*armatus*, p. 56.

a^2. Superomarginal plates entirely devoid of enlarged tubercles or spines; central granules or spinelets of paxillæ not enlarged on disk.

  b^1. Paxillæ smaller, about four or five transverse series opposite two superomarginals at base of ray; more or less irregular along radial lines; abactinal plates of papular areas of rays not lobed; upper edge of ambulacral ossicles not produced into a thin lamina between consecutive ampullæ, and bearing a comb-like series of irregular teeth or spinelets...........*californicus*, p. 61.

  b^2. Paxillæ larger, about three transverse series opposite two superomarginals at base of ray; paxillæ uniform in arrangement across ray; abactinal plates of papular areas very distinctly lobed; upper edge of ambulacral ossicles curiously compressed and produced into a thin lamina, bearing a few irregular teeth or spinelets; upper end of same ossicles toothed..*ornatissimus*, p. 67.

ASTROPECTEN ARMATUS Gray.

Pl. 5, figs. 1-2; pl. 7, figs. 3, 6; pl. 50, fig. 4; pl. 51, fig. 3.

Astropecten armatus GRAY, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 181 (not Müller and Troschel, Syst. Ast., 1842); Synopsis Starf. Brit. Mus., 1866, p. 3.—VERRILL, Trans. Conn. Acad., vol. 1, pt. 2, 1867, p. 332.

Astropecten erinaceus GRAY, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 182; Synopsis, 1866, p. 3.—VERRILL, Trans. Conn. Acad., vol. 1, pt. 2, 1867, p. 332.—PERRIER, Révision des Stellérides, 1875, p. 358.—SLADEN, *Challenger* Asteroidea, 1889, p. 734.—FISHER, Proc. Wash. Acad. Sci., vol. 8, 1906, p. 118.

Astropecten örstedii LÜTKEN, Vid. Medd., 1859, p. 159.—VERRILL, Trans. Conn. Acad., vol. 1, pt. 2, 1867, pp. 274, 328, 330.

Diagnosis.[a]—Size frequently large. Rays five. R = 129 mm.; r = 30 mm.; R = 4.3 r. Breadth of ray at base, 32 mm. Species variable in relative dimensions and in ornamentation. Sides of ray rather high, vertical. Marginal plates massive, the superomarginals encroaching more or less onto abactinal area, and usually armed with one or two short stubby spines, placed one above the other and forming two longitudinal rows of spines along ray except at base, where they may be as many as four spines to a plate, and at tip, where there is usually but one. Great variation in this respect; frequently only one series of spines, or rarely only a few scattered. Paxillæ fairly large, the central granules or spinelets larger than the peripheral. About three prominent lateral inferomarginal spines in an oblique series, with numerous accessory spinules on actinal surface. Adambulacral plates with three furrow spines, and on actinal surface a longitudinal series of two spines, the adoral small, somewhat flattened, the other greatly enlarged, subterete at base but much flattened beyond middle, and chisel-shaped or decidedly scoop-shaped at tip. Out side of this series, three or four spines, about equal to adoral member of above series, form an oblique irregular row or a group.

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[a] From a specimen in the Stanford collection, collected by E. C. Starks at San Diego, California, figured on pl. 5, fig. 1.

Description.—Paxillæ fairly large, those on disk and along proximal radial regions with spinelets very robust, short, globose, or with tips flattened and flaring. In large specimens two or more central spinelets are frequently fused together to form a very irregular plate or ossicle occupying the whole or a part of the tabulum of paxilla. Peripheral spinelets or paxilla robust, but smaller than the central ones; more uniform in size in small than in large specimens where they are of unequal caliber, often enlarged at tips and ten to fifteen in number. Paxillæ largest on radial regions at base of ray, decreasing in size toward margin of area, center of disk, as well as toward tip of ray.

When the abactinal integument is removed and examined from the cœlomic side the midradial areas are seen to be paved with irregularly arranged, subcircular, elliptical, or even faintly scalloped plates without papulæ between them. The areas occupied by these plates broaden at base of rays, and the central area of disk is also paved with similar ossicles, decreasing in size and overlapping more and more toward the very center. On the rays, the nonpapular areas are from three to four plates wide. On either side of this midradial area the plates are very much smaller, and at base of ray are not very regularly substellate or six-lobed, but soon become elongate as in the following species. The plates do not touch and are surrounded by six or five papulæ. On the interradial papular areas of disk the plates are stellate and usually touch. The connective tissue and muscle layer between the ossicles and cœlomic epithelium is thicker than in either of the following species. The arrangement of plates surrounding madreporic canal resembles that of *A. californicus*.

Superomarginal plates very massive and high, especially interradially, occupying two-thirds or three-fourths of the vertical side of ray, and encroaching conspicuously onto abactinal surface, about which they form a slightly raised border. There is a large degree of variation both in the size and amount of encroachment onto abactinal paxillar area. Variability in the latter respect affects the width of the paxillar area and considerably alters the general facies of the specimen. A large specimen[a] (*Albatross*, 1904) from San Diego Bay (Beacon 3 Shoal) has a row of small tubercles, one to a plate, all along the upper edge of series, extending about two-thirds the length of ray. These tubercles are very irregular in size and shape, sometimes becoming reniform or even cordate. Not quite half way to lower end of each plate is another small tubercle forming a similar but less conspicuous longitudinal series. Another large specimen, that from which the diagnosis is taken, has both series of tubercles well developed, the upper series extending nearly to tip of ray, the lower within two plates. Spines of lower series conical or bluntly bi- or tri-dentate at tip; those of upper series shorter, more irregular, often flattened, and apparently composed of two fused tubercles; sometimes two subequal or very unequal tubercles stand side by side at upper end of plate. On first plate three tubercles (shaped something like molar teeth) stand in a transverse row at upper end of plate, and below them two or three short conical spines, the lowermost in line with the lower longitudinal series. Scarcely two proximal plates are alike in armature. The opposite extreme is found in a large specimen from off San Pedro in which there is an inconspicuous tubercle at the upper end of a few of the proximal plates, the rest being unarmed. Any number of intermediate forms may be found between these extremes. General surface of plates covered with spinelets, which are flat, roundish, or polygonal and granuliform on the abactinal surface of ray, becoming slender and capillary in the fasciolar grooves and toward lower edge of plate.

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[a] See pl. 5, fig. 2.

Inferomarginals extending laterally slightly beyond superomarginals, or not at all. Armature consisting of about three or four tapering, slender, sharp, slightly flattened spines in an oblique series on outer end of plate, and two or three shorter, sharp, lanceolate spines on the aboral edge of the actinal surface of each plate. Numerous shorter, lanceolate or blunt spinules usually accompany the regular series. The actinal spines are broader, flatter, and more blade-like in some specimens than others and the larger lateral spines vary considerably in length in proportion to width of ray (one-fifth to one-half width), while some are slenderer and less obviously flattened than others. General surface of plates is covered with flattened, round-tipped, squamiform spinelets.

Adambulacral plates with an angular furrow margin. Furrow spines three, of the usual astropectinoid type; central spine slightly longer than the two laterals, compressed, blunt; lateral spines of series flattened, tapering, blunt. On actinal surface, just behind furrow series, is a longitudinal series of two spines, the adoral somewhat flattened, equal to or shorter than adjacent furrow spine; the aboral spine greatly enlarged, subterete at base but much flattened beyond middle and chisel-shaped or decidedly scoop-shaped at tip. In large specimens this spine is 4 to 6 mm. long and 2 mm. broad at tip. Outside of this series, three or four flattened spines, about equal to adoral member of above series in length, form an oblique, irregular, or a longitudinal row, or a group. Sometimes at base of ray the aboral member of the outer series is also enlarged, but it never attains the size of the large spine. The great size of the enlarged spine often pushes the adoral member out of place, usually toward the furrow.

Mouth plates prominent actinally and rather narrow. Armature variable. In large specimens there is usually a single series of prominent, blunt, or truncate, flat spines parallel with suture between the two plates and increasing in size toward the inner end of plate. On free margin of plate is an irregular series of much smaller spines, and between the two numerous very short subconical spinelets. Sometimes a second superficial series, smaller than the regular one, closely parallels it. The first adambulacral plate is much compressed and bears two closely appressed transverse series of truncate spines, fairly regular in small examples, but irregular in large.

Actinal interradial areas very small, paved with eight to twelve paxilliform plates, sometimes even fewer, the spinelets being similar to those on adjacent parts of the inferomarginals—i. e., slightly tapering, terete or flattened at tip, and skin covered. In specimens with very spiny superomarginals, the actinal intermediate paxillæ usually bear one or occasionally two stout tapering spines, surrounded by the smaller spinelets. Many specimens do not have this spine. Actinal intermediate spines are strongly developed in a large specimen from San Diego, from which the diagnosis is drawn.

Superambulacral plates well developed. Under edge of ambulacral ossicles normal, and smooth, not produced into a thin lamina between consecutive ampullæ, nor toothed in any way. Gonads axillary. Six Polian vesicles, two in the interradius containing the madreporic canal (one on either side of it), and one in each of the other four interradii.

Madreporic body large, exposed, 5 to 6 mm. in diameter (in big examples), the adcentral edge about midway between center of disk and edge of marginal plates. Striations very irregular often with tiny protuberances along ridges, these sometimes fusing after the manner of the central granules of the paxillæ.

Variations.—This species, as has already been said, varies greatly, not only in respect to many details of ornamentation but also as regards dimensions, the relative size of rays and disk, and the width of paxillar area. It is not surprising, therefore, that the general appearance should also differ considerably, according as the rays are long or short, or the superomarginals encroach considerably upon the paxillar area, or as the latter are very spiny or not, or as the inferomarginals extend laterally beyond the superomarginals. If one encountered the isolated extremes he would certainly be justified in regarding them as examples of distinct species. It is not at all improbable that several species now regarded as distinct may really belong to this variable species. The character of the paxillæ and of the inferomarginal armature appears to be more stable than that of the marginal plates and is hence more valuable in an offhand determination of specimens.

A few specimens have been analyzed to show some of the more obvious differences or variations.

Table showing variations in Astropecten armatus.

Locality.	R in mm.	r in mm.	R:r.	Number of superomarginals.	Upper row of superomarginal spines present.	Lower row present.	Inferomarginals extend beyond superomarginals.	Width of paxillar area, base of ray.
San Diego	129	30	4.3:1	36	×	×	......	27
Do	150	30	5:1	42	× [a]	......	......	21
San Pedro	103	20	5.1:1	40	1 or 2 spines [b]	Scattered spines	×	15
Do	108	25	4.3:1	38	3 or 4 spines [b]	× [a] [c]	×	18
Do	62	18	3.4:1	30	5 or 6 spines [b]	× [a] [c]	Trifle.	17
Do	105	23	4.6:1	39	3 or 4 tubercles [b]	......	×	20
Do	32	9	3.5:1	25	1 spine [b]	× [a] [c]	Trifle.	5

[a] Absent from terminal fifth of ray. [b] At base of ray. [c] Absent from first five or six plates.

The smallest specimen of this species I have seen has R=17 mm. and a few enlarged superomarginal tubercles. The central spinelet of paxillæ is granuliform and subglobular and the enlarged adambulacral spine is square cut at base of ray. These features will serve to distinguish small specimens from young of *californicus* and *ornatissimus*, in which the central granules of paxillæ is not more robust than the peripheral ones, and where there are never superomarginal tubercles or spines.

Type-locality.—"Puerto Portrero, South America, on sandy bottoms, 9 fathoms, H. Cuming, Esq." (Gray).

Distribution.—Ranges from San Pedro, California (and probably from north of this point) to Ecuador (Punta St. Elena, Puerto Portrero). Only Californian specimens have been examined, however. Shore to about 30 fathoms.

Specimens examined.—Thirty-four from San Pedro and San Diego, as follows:

Specimens of Astropecten armatus examined.

Locality.	Depth.	Nature of bottom.	Number.	Collection.
	Fathoms.			
Long Beach, California			1	U. S. Nat. Mus.
San Diego, California	Shore.	sandy	1	Stanford University.
San Diego, California, Beacon 3 Shoal			1	*Albatross*, 1904.
San Pedro, California (II-2)[a]	2½	seaweed	1	University of California.
San Pedro, California (III-1)	7	dark-brown mud	7	Do.
San Pedro, California (VI-1)	11¼	shore sand	6	Do.
San Pedro, California (XV-1)	4	coarse sand	7	Do.
San Pedro, California (XVI-3)	13		4	Do.
San Pedro, California (XIX-2)	102-30	soft sandy mud	1	Do.
No locality			5	Do.

[a] Station and haul, University of California Series.

Remarks.—This species is so variable that it is difficult to make its positive characters intelligible through the median of description. It bears a great resemblance to *Astropecten duplicatus* Gray, from which it differs in having broader rays relative to the length, heavier paxillar granules, much stouter and longer inferomarginal spines, and more conspicuously enlarged subambulacral spines. In *duplicatus* the superomarginal plates encroach more onto the paxillar area (width equals more than one-half paxillar area) and are not nearly so high as in *armatus*, the ray being more depressed.

Armatus may be distinguished from the other two Californian astropectens by the presence of at least a few superomarginal spines or tubercles, by the broader and more tumid superomarginal plates, by the enlarged central granules of the paxillæ, by the heavier and more bristling inferomarginal armature, and especially by the chisel-shaped enlarged adambulacral spine, which is broader at tip than at base, and usually more or less hollowed at the end, on the upper (or outer) side, like a gouge. Even young specimens of *armatus* have a few superomarginal tubercles, although these are usually inconspicuous. In lieu of the superomarginal spines the enlarged central granules of paxillæ and the specialized adambulacral spine may be used to determine doubtful specimens.

The name *erinaceus* has usually been used for this species. Perrier considers Lütken's *örstedii* and Gray's *armatus* to be identical with *erinaceus*, and in view of the great variability of the species, he is probably correct. The name *armatus*, however, has page priority over *erinaceus*. The *Astropecten armatus* of Müller and Troschel, 1842, is a homonym of this species and a synonym, according to most authors, of *A. polyacanthus* of the same writers. It consequently does not affect the validity of Gray's name, which has two years priority.

ASTROPECTEN CALIFORNICUS Fisher.

Pl. 6, figs. 1, 2; pl. 7, fig. 1; pl. 50, fig. 5; pl. 51, figs. 2, 2*a*.

Astropecten californicus Fisher, Zool. Anz., vol. 30, June 19, 1906, p. 299.

Diagnosis.[a]—Rays five. R = 100 mm.; r = 18 mm.; R = 5.5 r. Breadth of ray at base, 20 mm. (measured between first and second superomarginal plates).

Disk small; rays long and narrow, pointed; interbrachial angles rounded; abactinal surface plane or arched, bordered by narrow margin formed of superomarginal plates which are confined chiefly to side wall of arm; superomarginals without enlarged spines or tubercles; inferomarginals rather narrow with transverse aboral series of about three spines on edge of ray, continued actinad along aboral edge of plate in two to four smaller-spaced spinules; adambulacral spines in about three parallel longitudinal series, the aboral spine of the middle series of two or three conspicuously flattened, round-tipped and stouter than others (see p. 62); paxillæ small to medium sized, about four or five transverse series, corresponding to two superomarginals at base of ray, six or seven at middle and about eight to ten near tip. Upper edge of ambulacral ossicles smooth.

Description.—Abactinal paxillæ fairly uniform in arrangement, and usually compact, largest on outer half of radius of disk, decreasing in size toward center of disk, very quickly toward margin, and gradually along rays toward tips; arranged in definite transverse rows along sides of paxillar area of rays, elsewhere without regularity. Crowns of paxillæ circular or broadly elliptical when spinelets are radiating, more irregular when spinelets stand erect and compact. Each paxilla pedicel surmounted (in larger paxillæ) by fifteen to twenty short, stout, round-tipped or subtruncate, often clavate spinelets in a peripheral series, and eight to fifteen in center. When the spinelets are crowded together the paxilla is flat-topped and the tips of the spinelets resemble flat-topped granules. In many specimens the spinelets are slender and stand on the pedicel more like the petals of a flower. These specimens usually have the paxillæ more definitely spaced, with fewer spinelets—ten to fifteen in peripheral and five to eight in the central group. Opposite the suture between second and third superomarginal plates about eighteen to twenty paxillæ can be counted across ray to similar point on opposite side.

The bases of the paxillæ or abactinal plates are subcircular and slightly overlapping, without papulæ between, along midradial areas and central portion of disk. Along the ray this radial area of roundish plates is about five plates wide and is broader than the same region in *A. ornatissimus*. The plates are irregularly arranged, without evident spaces between except occasionally on disk. On either side of the radial areas the plates are very regularly arranged in transverse rows, are six-sided but much longer than wide; far along ray they become rudely elliptical, with truncate ends, and on disk broader than on base of ray. Faint lobes are sometimes seen, but the plates are not distinctly lobed as in *ornatissimus*. In these lateral regular series two papulæ occur between every two plates, each plate being surrounded by six. On the disk the papulæ are confined to the interradial angles. A very large plate stands on the adcentral side of the madreporic body, and on either side of this a slightly smaller one, while four others, much smaller, complete the circle.

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[a] Diagnosis and description based on specimen from station 4559, Monterey Bay, California; 22 to 8 fathoms, fine gray sand.

Superomarginal plates forty-six or forty-seven from interradial line to extremity of ray are wider than long, the length increasing, the width decreasing toward end of ray; and they gradually encroach more and more onto abactinal surface as they proceed along ray. Plates form an arched bevel to distal half of abactinal edge of ray, and a rounded lateral margin to ray in proximal portion. Plates slightly tumid along aboral edge, and covered with low granuliform spinelets squamiform in middle of upper half, thence decreasing in size and becoming slender toward margins of plate. No enlarged spinelets or tubercles on any of the superomarginal plates.

Inferomarginals corresponding exactly to superomarginals, but not extending laterally beyond them except a very little, sometimes, near end of ray. Armature consists of a series of five or six slender, tapering, sharp, slightly curved spines and spinelets along aboral edge of plate; of these, three stand on outer end of plate, forming a triple series all along margin of ray, the middle spine being longest of the three and about equaling in length the width of plate; on actinal surface two or three spaced, sharp, slightly flattened, much shorter spines continue this series to inner end of plate. Adorally to the three marginal spines and close to them, four or five sharp, flattened spinules (shorter than inner spines of above series) form an oblique row meeting the aboral series just below the inner spine of marginal row (which is also set transversely oblique). There may be four spines in the marginal series, and usually on the first four plates the largest spine is broader, flattened and lanceolate or oblong-lanceolate in shape. It is here only about one-half as long as width of plate. General surface of plates covered with flattened, round-tipped, upright, papilliform spinelets, increasing slightly in size toward the auxiliary lateral spinules.

Adambulacral armature in three or four fairly regular longitudinal series. (1) Furrow spines three, the central longest and saber-shaped when dry, the laterals shorter and slender when dry, but in life with more or less evident membranous expansions at base, giving the spine a flattened appearance. (2) First actinal series consisting of two or three slightly shorter spines, of which the aboral is very much the stouter, being flattened with a rounded or truncate tip. The adoral spine is shorter and when there are three in the series they are graduated in length. (3) On outer half of plate are two to five shorter slightly flattened spines either in an irregular group, or forming a series of two or a series of three, with one out of line in addition, or sometimes two series of two. In large specimens the armature is less regular. Sometimes a series of two smaller spines is interpolated between the furrow series and the first actinal, or again only one such spine. Irregularity is frequent on plates near the mouth, but usually the larger flattened spine is recognizable on the actinal surface. First adambulacral much compressed, the second less so; former with a double transverse series of closely appressed spines, about 30 in number.

Combined mouth plates narrow with a crowded armature consisting of three series, a marginal, rather high on side of furrow, an intermediate, and most conspicuous of all, a superficial, the latter consisting of a nearly straight series of fourteen or fifteen short flattened, round or square-tipped, or subacute spines, increasing rapidly in length toward inner angle of plate, where there is an enlarged tooth (or two to each mouth angle). Marginal spines small, forming an angular series of seven or eight, between base of tooth and inner end of first adambulacral plate, thence continued along side of first interadambulacral suture in the form of a few straggling very small spinelets. Intermediate series extending whole length of plate, parallel and close to superficial series, against which the much smaller spinelets are often appressed. All spines more acute, and somewhat slenderer in dried specimens.

Actinal interradial areas very small, having six small paxilla to each area, one opposite each of the first three adambulacrals. Each paxilla bears several (four to seven) closely grouped, clavate skin-covered, papilliform spinelets. Fewer than six plates may be present.

Superambulacral plates well developed. The upper edge of the ambulacral ossicles, though sharp, is not produced upward into a thin lamina provided with irregular comb-like teeth as in the following species. This fact will serve to distinguish *californicus* at a glance. A Polian vesicle in each interradius except that containing the madreporic canal, which has two; the same interradius has two septa. Gonads axillary, not extending along rays.

Madreporic body partially concealed by paxillæ, situated about one-third distance from margin to center of disk; striations deep, irregularly centrifugal; ridges with numerous little knobs.

Color in life, ferruginous to light claret brown above, lighter below.

Variations.—The chief variation in this species is due to the relative size of specimens, the large examples having long, narrow rays, the small ones having shorter thicker rays. As fully seven-eighths of the specimens from off the southern part of California are small, and the majority of those from Monterey Bay are large it would seem, if one had only a few examples, that the southern form had shorter rays. Several good-sized specimens collected by the *Albatross* in 1889 off the Santa Barbara Islands have rays fully as long, however, as average specimens from Monterey Bay, while small examples from the latter locality are of about the same dimensions as equal-sized examples from southern California. It is possible that the region about Monterey Bay is more favorable for the species and that it therefore develops to larger size than in southern waters.

Specimens from Monterey Bay of nearly the same size vary in respect to the length and width of ray, some specimens having narrower, or more pointed rays than others, but as shown in the accompanying table these differences are not great.

Table showing variations in Astrapecten californicus.

Station.	Locality.	R in mm.	r in mm.	R : r.	Number of superomarginals.	Width of ray at base.	R is to breadth of ray as:
4559	Monterey Bay	100	18.0	5.5:1	46	20	5:1
4439	....do	94	16.0	5.87:1	50	17	5.53:1
4453	....do	94	17.0	5.53:1	55	17	5.53:1
4453	....do	93	13.5	6.88:1	51	15	6.2:1
	....do	90	19.0	4.73:1	43	20	4.5:1
2975	Off Santa Cruz Island	79	13.5	5.1:1	45	15	5.33:1

Variations due to size are shown in the following table:

Table showing variations due to size in Astropecten californicus.

Station.	Locality.	R in mm.	r in mm.	R : r.	Number of superomarginals.	Width of ray at base.	R is to breadth of ray as:
4420	Monterey Bay	11	4.5	2.44:1	14	5	2.2:1
4420	do	21	8.0	2.62:1	20	7	3:1
4422	do	32	10.0	3.2:1	27	10	3.2:1
4535	do	52	14.0	3.7:1	32	14	3.7:1
4453	do	70	15.0	4.7:1	46	16	4.4:1

Besides variations in dimensions, some specimens have the superomarginal plates encroaching onto abactinal surface more than others, especially at base of ray; and the paxillæ vary slightly in specimens of the same size. Some examples have the paxillæ more crowded and their spinelets may be shorter and more granuliform, as well as thicker in caliber. This causes the paxilla itself to appear more compact and alters somewhat the general facies of the specimen. In specimens with slender paxillar spinelets the abactinal area is more open on the rays. The flattened granules on the superomarginal plates are coarser in some specimens than others. The outer actinal adambulacral spines vary somewhat in arrangement, but the enlarged spine is always flattened in a longitudinal plane and has a round or subtruncate tip.

Young.—The young of course have shorter arms, fewer marginal plates, and smaller paxillæ. In a specimen with R = 20 mm. (r = 6 mm.; R = 3.3 r) there are four or five transverse rows of abactinal paxillæ opposite every two superomarginals at base of ray, and about twelve to fifteen paxillæ in a transverse row opposite second superomarginal. These are smaller than in a corresponding example of *A. ornatissimus*, the smaller and more irregular paxillæ of the midradial line and center of disk of *californicus* being particularly well marked. In *ornatissimus* there is no difference in the midradial region. Lateral spines in examples of this size are one to three, the auxiliary lateral spines being poorly developed or absent. (Compare with corresponding stage of *ornatissimus*). Actinal inferomarginal spinelets are inconspicuous, and frequently there is only one series of actinal adambulacral spines, the enlarged spine being not nearly so well developed as in the corresponding stage of *ornatissimus*. The third series when present is represented by one or two spinelets slightly shorter than those of first or inner actinal series. Most of the small specimens have a prominent epiproctal cone.

Type.—No. 157, Stanford University invertebrate collection.

Type-locality.—Monterey Bay, California; 70 fathoms (approximately).

Distribution.—From north of Bodega Head (north of Point Reyes), California, to Lower California; 10 to 244 fathoms. This species is one of the commonest in the shallower depths of Monterey Bay as determined by the steamer *Albatross* in 1904. It is abundant also off San Pedro, where it has been collected in considerable numbers by the staff of the Biological Station of the University of California (1901).

Specimens examined.—The following is a complete list of localities, Californian except as noted, from which in all 1,458 specimens have been examined:

Specimens of Astropecten californicus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2894	Off San Miguel Island	53	stones, broken shells	1	U. S. Nat. Mus.
2900	Off Point Conception	13	sand	5	Do.
2902	Off Santa Cruz Island	53	fine gray sand	2	Do.
2906	Off Point Conception	96	sand, mud	2	Do.
2908	do	31	gray sand	1	Do.
2911	Cortes Bank	60	rocks, sand	7	Do.
2913	do	26	broken shells	18	Do.
2915	do	55	gray sand	2	Do.
2918	do	67	fine gray sand	3	Do.
2922	do	47	do	5	Do.
2926	do	69	do	1	Do.
2930	Los Coronados Islands, Lower California.	60	mud	10	Do.
2931	do	34	gray sand, shells	27	Do.
2933	do	36	gray sand	30	Do.
2934	Off San Diego	36	do	5	Do.
2938	San Pedro Bay	47	fine gray sand, stones	21	Do.
2941	do	26	shells, stones	2	Do.
2942	do	20	gray sand	1	Do.
2950	Between Santa Rosa and Santa Cruz Islands.	21	gray sand, broken shells	2	Do.
2952	Off Santa Rosa Island	57	broken shells, rocks	2	Do.
2962	Off Santa Barbara	165	sand, stones, coral	2	Do.
2963	do	20	do	16	Do.
2964	do	21½	sand stones	16	Do.
2965	do	27	fine gray sand	3	Do.
2967	do	30	coarse mud	50	Do.
2969	do	26	gray sand, pebbles, stones	55	Do.
2970	do	29	fine gray sand, mud	135	Do.
2971	do	29	do	57	Do.
2972	do	61	green mud	4	Do.
2973	do	68	do	4	Do.
2974	do	73	do	3	Do.
2975	Off Santa Cruz Island	36	gravel, broken shells	2	Do.
2983	East of Guadalupe Island, Lower California.	58	gray sand, broken shells	4	Do.
3106	Off Half Moon Bay	77	fine gray sand	1	Do.
3135	Off Santa Cruz	15	do	15	Do.
3145	Monterey Bay	56	do	1	Do.
3147	South of Point Ano Nuevo	56	brown mud	3	Do.
3148	Off Point Ano Nuevo	47	do	1	Do.
3164	Point Reyes	61	rocky	1	Do.
3172	Northwest of Bodega Head	62	black sand	2	Do.
3190	Between Cape St. Martin and Piedras Blancas.	53	fine gray sand	2	Do.
3478	Monterey Bay	68	gray sand, mud	1	Do.
3671	do	56	green mud, sand	1	Do.
3207	North of Monterey Bay	108	fine gray sand	6	Do.
	Monterey Bay			17	Do.
	Off Santa Barbara	31		1	Do.
	Off San Diego	124		5	Do.
	No locality[a]			46	Do.

[a] Several bottles broken and the contents scattered by California earthquake, 1906.

Specimens of Astropecten californicus examined—Continued.

Station	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
3207	Off Cerros Island, Lower California.			3	U. S. Nat. Mus.
	Monterey Bay	About 70		4	Stanford University.
4304	Vicinity of San Diego	25	coarse yellow sand, shells, gravel.	11	*Albatross*, 1904.
4332	do	62–183	gray sand, rocks	2	Do.
4343	Near Los Coronados Islands, Lower California.	55–155	fine gray sand	3	Do.
4344	do	244	rocky	3	Do.
4346	Off San Diego	46–50	dark green mud, fine sand	3	Do.
4349	do	82–134	green mud	1	Do.
4384	do	164–85	gray sand	1	Do.
4420	Between Santa Barbara and San Nicholas Island.	32–33	fine gray sand	156	Do.
4421	do	229–298	gray mud, rocks	3	Do.
4422	do	31–32	gray sand, shells	55	Do.
4431	Off Santa Rosa Island	30–41	mud, gray sand, rocks	15	Do.
4439	Monterey Bay (northeast of Point Pinos).	42–40	gray sand, shells	1	Do.
4452	do	49–50	green mud	9	Do.
4453	do	49–51	dark green mud	12	Do.
4457	do	46–40	do	1	Do.
4464	Monterey Bay (southwest of Moss Landing).	51–36	soft, dark gray mud	3	Do.
4473	Monterey Bay (north of Point Pinos).	54–65	gray sand, mud	7	Do.
4476	Monterey Bay (southwest of Moss Landing).	25–39	soft green mud	1	Do.
4477	do	19–11	do	2	Do.
4492	Monterey Bay (off Hill's Landing).	26	do	1	Do.
4501	do	12–11	hard sand	3	Do.
4535	Monterey Bay (3 miles off Pyramid Point).	71–54	hard gray sand	1	Do.
4548	Monterey Bay (between Italian Ledge and shore).	46–54	coarse sand, shells, rocks	4	Do.
4550	Monterey Bay (near Italian Ledge).	50–54	green mud, rocks	4	Do.
4551	do	46–56	coarse sand, shells	1	Do.
4552	Monterey Bay (70 Fathoms Bank).	73–66	green mud, rocks	1	Do.
4555	do	66–69	do	1	Do.
4556	Monterey Bay (Italian Ledge)	50–59	rocks	16	Do.
4557	Monterey Bay (Portuguese Ledge).	53–54	do	5	Do.
4559	Monterey Bay (off Mussel Point	22–8	fine gray sand	1	Do.
4562	Monterey Bay (vicinity of Santa Cruz).	10	hard sand	30	Do.
	Off San Pedro[a]	2½–102	hard and soft sand, green mud, brown mud and pebbles.	493	University of California.

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[a] These specimens, kindly sent by Prof. W. E. Ritter, were taken at twenty-nine different hauls, ranging in depth from 2½ to 102 fathoms, but the majority from depths of less than 30 fathoms (nineteen hauls). The bottom was sand together with shells, shale, cobbles, pebbles, or sand alone; less frequently mud or sandy mud (seven hauls). Many of the specimens are quite small.

Remarks.—Four species of *Astropecten* from Mexico and Central America must be considered in connection with *A. californicus*. *A. fragilis* Verrill, Panama to Peru,[a] is a slender rayed form with a narrow paxillar area on the rays and a small tubercle at upper end of the proximal superomarginals (apparently characteristic). All the adambulacral spines are slender, the middle furrow spine exceeding width of plate. The enlarged subambulacral spine is still longer, slightly tapered, with a slight groove on the upper or outer side near the bluntly pointed tip. Adorad is a very slender spinelet in line, and behind the two are two or three capillary spinelets. Inferomarginal spines two, rather broad.

A. regalis Gray (San Blas and south) is a short-rayed species (R=3 r) and has one sharp enlarged actinal adambulacral spine, scarcely longer than the longest furrow spine. *A. verrilli* de Loriol (Mazatlan) is likewise a comparatively short-rayed form (R=3.4 r) and differs from *californicus* in having small tubercles on the superomarginal plates, forming a single longitudinal series. The inferomarginal and adambulacral armature is also slightly different. *A. rubidus* de Loriol (Mexico) is allied to *articulatus* (Say), having broad superomarginal plates, a smaller disk than *californicus*, with rays broader at tip, paxillæ with shorter spinelets, adambulacral plates with much smaller spinelets—three small ones in actinal series. The minor details of inferomarginal armature are different.

Until an extensive series of Mexican and southern Astropectens is compared by one man it will not be possible to determine the validity of the rather numerous nominal species. It is highly probable that several so-called species are variations of a single form. Neither is it possible at present to determine the limits of Gray's species, for his descriptions are nearly useless. The species called *armatus* may eventually be divided into several races, as Lütken's *örstedii* seems to differ in some respects from typical *armatus* (a specimen in the Yale Museum, no. 817, having been examined).

Although *californicus* and *ornatissimus* seem to be perfectly distinct, they may eventually be found to intergrade with southern species.

In the Museum of Comparative Zoölogy (No. 190) are two medium-sized specimens of *californicus* with rather shorter than typical rays and decidedly truncate enlarged subambulacral spine. These are supposed to come from Alaska, but the locality is not correct. As the *Albatross* in her numerous Alaskan dredgings has never secured the species (or even north of central California) I have not considered the record authentic.

ASTROPECTEN ORNATISSIMUS Fisher.

Pl. 6, figs. 3, 4; pl. 7, fig. 2; pl. 51, figs. 1, 1a–c.

Astropecten ornatissimus Fisher, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 119.

Diagnosis.—Resembling *A. californicus* in general features, but differing in having larger paxillæ, longer, slenderer, and more distinctly spaced paxillæ spinelets; in having the paxillæ superficially more uniform in size across the ray, not more elongated along midradial line, and smaller over a large area at center of disk; in having longer, slenderer, and more tapered adambulacral spines; in having the upper edge of each ambulacral plate produced into a thin lamina between consecutive pairs of ampullæ, the free edge bearing a comb-like series of slender but irregular teeth or spinelets. R=56 mm.; r=14 mm.; R=4 r. Breadth of ray at base, 16.5 mm. (type).

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[a] A specimen in the Yale Museum No. 1302, Zorritos, Peru, has been examined.

Description.—The paxillæ afford the most evident difference between *ornatissimus* and *californicus*. In *californicus* there is a considerable area around center of disk in which the paxillæ are smaller and more crowded than on remainder of disk and on rays, and paxillæ of midradial regions are more irregular, at least in arrangement, than along margins of ray. In the present form the large paxillæ extend nearly to center of disk, there being only a small area of small paxillæ.

The paxillæ of sides of rays are not in such regular rows and are not easily differentiated from the midradial ones. About three or three and one-half transverse series of paxillæ correspond to two superomarginal plates at base of ray (usually five in *californicus*), about five at middle of ray and six or seven near tip. Opposite suture between second and third superomarginal plates about twelve or thirteen paxillæ can be counted across ray to same point on opposite side (eighteen to twenty in *californicus*). Large paxillæ at base of rays with fifteen to eighteen peripheral and ten to fifteen central spinelets, which are much longer than in *californicus*, terete, with rounded or clavate tips. Tabulum of paxilla fairly broad so that both central and peripheral spinelets appear spaced, giving the whole an open floriform appearance. Farther along ray, one to six central spinelets to a paxilla, and upwards to fifteen or eighteen peripheral. At very end of ray the paxillæ are much smaller.

Although superficially there is little difference between the paxillæ of the midradial line and those along sides of area, the plates or bases of the paxillæ are very different. If the dorsal integument is removed, treated with caustic potash and viewed from the inner or cœlomic side the outline of the plates is readily seen. Those along the midradial line and on center of disk are subcircular or very obscurely lobed, are without papulæ between them, and imbricate strongly, especially on disk. In large specimens the plates are usually entire, and roundish, but tend to become lobed adjacent to the papular areas. On the ray these same plates become more elliptical and irregular in outline as well as arrangement. Two or three series have no papulæ between them. On either side of the midradial line of entire plates as well as over the interradial triangle of disk the plates are smaller, strongly lobed, and touch or overlap by these lobes, allowing the papulæ to pass between. On the ray each plate is longitudinally elongated, subelliptical with two short but abrupt lobes at either end. The plates of consecutive transverse rows alternate so that the processes join every plate with four others, two adorally and two distally. Between any two plates there are, as a rule, two papulæ in a longitudinal row, a single plate having six papulæ surrounding it. On the disk these plates are less regular and frequently have as many as six lobes. Occasionally the slender lobes appear as independent ossicles. In the largest specimen examined the regular plates on ray do not touch one another, but do so regularly in a medium-sized example. On the adcentral side of the madreporic canal where it pierces the dorsal integument is a large convex plate, hollowed on the side toward the canal; on either side of this, forming a sort of horseshoe around the canal, are two other smaller, slenderer plates, closely joined to the large one. The side toward marginals is without a specialized raised ossicle.

Superomarginal plates thirty-two to a ray, without enlarged spinelets or tubercles. General surface covered with short spinelets, delicate except along median transverse line where they are clavate to thimble-shaped, increasing in size toward upper end of plate (same spinelets are markedly squamiform in *californicus*).

Armature of inferomarginal plates very similar to that of *californicus*, there being usually two or three marginal spines obliquely placed, and, in a line, three more spaced, smaller, spines along aboral edge of plate. The auxiliary lateral spines situated just adorad to the regular lateral spines on each plate are longer than the same spines of *californicus*.

Adambulacral furrow spines three or four, similar to those of *californicus*. First actinal series with two spines, the aboral being much the longer, tapering, slightly flattened, bluntly pointed, longer and slenderer than the corresponding spine of *californicus*. The adoral member is about as long as the furrow spine which stands opposite. Outer or second actinal series usually consists of three slender untapered spines somewhat shorter than furrow spines and standing in a fairly regular row. Near base of furrow two or three very small spinelets sometimes stand on outer end of plate.

Actinal interradial areas very small, paved with six or eight paxilliform plates in large specimens. Each paxilla bears a floriform group of about eight to twelve slender spinelets, of unequal thickness (more or less), those in center being usually the stoutest. Occasionally there is a single central sharp spine. In specimens from off Lower California, and to a less extent in those from off San Diego, the spinelets are, on some of the plates, grouped or coordinated to form a sort of pedicellarian apparatus. Even the spinelets on the actinal surface of the adambulacral plates are frequently arranged in a similar manner. As a whole the interradial areas may be said to be very inconspicuous.

Mouth spines similar to those of *californicus*, but the marginal series stand slightly spaced from the intermediate spines, so that inner end of combined plates is broader and the three series, superficial, intermediate, and marginal, are more clearly evident. All spines are slenderer and a trifle longer than in *californicus*. Marginal spines, about seven between tooth and inner end of first adambulacral plate, and about six or seven more minute spinelets continue the series two-thirds distance to outer end of plate.

Madreporic body concealed by paxillæ, situated as in *californicus* and crossed by sinuous striæ; tiny, spiniform knobs on ridges of *californicus* apparently lacking.

Superambulacral plates well developed. The upper edge of each ambulacral ossicle is produced into a thin lamina or ridge between consecutive pairs of ampullæ, the free edge being sharp and provided with very slender, irregular teeth, five or six in number. These give the appearance of a comb. The upper end of each plate is produced into a knob, bearing several very slender spinelets; or the knob may have a sharpened edge bearing teeth. Between the knobs of opposite plates pass the transverse muscles of the ambulacral ridge. Very tiny spinelets are discoverable between consecutive knobs and transverse muscles of the ambulacral ridge. The presence of a comb of spinelets or teeth on the upper edge of the ambulacral plates will serve to distinguish this species from *californicus*, especially when other characters fail. Gonads arranged in a tuft on either side of the interradial line. Six Polian vesicles present, one in each interradius except that of madreporic canal, in which there are two; the same interradius having a double interradial septum, the others a single. Two Tiedemann glands to each interradius.

Color in alcohol, bleached yellowish to whitish; color in life unknown.

Variations.—The variations in this species mostly concern minor details of ornamentation—characters which are unstable in nearly all species of starfishes. Thus the spinelets are fewer in small specimens and are slightly more robust in some than in others. As usual the smaller specimens have shorter, stouter arms. There are a relatively few specimens of *A. californicus* (stations 3145, 3147, 3148, 3172) which bear a certain resemblance to *ornatissimus*, chiefly because the paxillæ are larger and more uniform, as seen superficially, than in typical examples. The paxillar spines, however, are shorter and more compact and the auxiliary inferomarginals spines (that is, the lateral ones) are short, while the comb of teeth on the ambulacral plates, described above, is entirely lacking. Likewise the enlarged adambulacral spinelet is of character of *californicus*—much flattened, relatively short with a round tip, and not very conspicuously tapered. It is barely possible that some of these aberrant examples of *californicus* may be hybrids. There is no good evidence that the two species intergrade, although it is not impossible or even improbable that they may converge somewhere off Lower California. The forms, though different, are so similar in general structure that one is impressed with the notion that they may be offshoots of a common species still living in the south, possibly *A. verrilli* or a nearly related form. There is a wide difference, though, in the toothed and smooth upper edge of the ambulacral plates.

Young.—In small specimens of *ornatissimus* the characters of the adult are fairly obvious, especially when examples are compared with equal-sized individuals of *californicus*. The paxillæ are large and the superomarginal plates encroach onto the abactinal area rather more than in the adult. In a specimen with R equal to 20 mm. (r=6.5 mm.; R=3r) there are about three transverse rows of abactinal paxillæ opposite every two superomarginals at base of ray, and about ten paxillæ to a transverse row, opposite the second superomarginal. Superomarginal plates, twenty; lateral spines of inferomarginals, two or three, the auxiliary lateral spines well developed and actinal inferomarginal spinules prominent. Adambulacral armature similar to that of adult, the long spine of second series (first actinal) well developed. Usually there are only two actinal series each with two spines, the outer shorter than those of furrow series.

Changes in dimensions due to size are shown in the following table:

Table showing variations in Astropecten ornatissimus.

Station.	R.	r.	R∶r.	Breadth of ray at base.	No of superomarginal plates.
4309	26	8.0	3.25 : 1	9.0	21
4364	36	9.0	4 : 1	11.0	25
4306	43	9.5	4.5 : 1	11.0	28
4413	56	14.0	4 : 1	16.5	32
4413	68	14.0	4.8 : 1	16.5	40

Type.—Cat. No. 21927, U.S.N.M.

Type-locality.—*Albatross* station 4413, between Santa Catalina and Santa Barbara islands, in 152 to 162 fathoms, on gray sand.

Distribution.—Vicinity of Guadalupe and Cerros islands, Lower California, north to vicinity of Santa Catalina Island, and San Pedro, California; undoubtedly ranging much farther south. Bathymetrical range, 47 to 162 fathoms.

Specimens examined.—The following is a list of localities from which one hundred and fifty-four specimens have been examined:

Specimens of Astropecten ornatissimus examined.

Station.	Locality.	Depth. Fathoms.	Nature of bottom.	No.	Collection.
2921	Cortes Bank, off San Diego, California.	145	fine gray sand	5	U. S. Nat. Mus.
2935	Off Point La Jolla, near San Diego, California.	124	do	68	Do.
2983	East of Guadalupe Island, Lower California.	58	gray sand, broken shells	3	Do.
3662	Off Avalon, Santa Catalina Island, California.	47	fine gray sand	1	Do.
	Not recorded			1	Do.
	Off Cerros Island, Lower California.			12	Do.
	Near San Diego, California			4	University of California.
	San Pedro, California			10	Do.
4305	Off San Diego, California	67–116	gray sand, shells	6	*Albatross*, 1904.
4306	do	207–497	green mud, fine sand	1	Do.
4309	do	67–78	fine sand, shells, rocks	27	Do.
4310	do	71–75	green mud, fine sand	5	Do.
4349	do	81–134	green mud, fine sand	5	Do.
4364	do	101–129	gray sand, mud, rocks	1	Do.
4385	do	89–90	coarse sand, rocks	2	Do.
4413	Between Santa Catalina and Santa Barbara islands, California.	152–162	fine gray sand	3	Do.

Remarks.—This species differs from *A. fragilis*, *A. regalis*, *A. verrilli*, and *A. rubidus* in the same respects as does *A. californicus*.

Genus PSILASTER Sladen.

Psilaster SLADEN, Narr. *Challenger* Exp., vol. 1, 1885, p. 611. Type, *Astropecten andromeda* Müller and Troschel; *Challenger* Asteroidea, 1889, p. 221.

Bathybiaster FISHER (not Danielssen and Koren), Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 295.

Plutonaster LUDWIG (not Sladen), Mem. Mus. Comp. Zoöl., vol. 32, July 17, 1905, p. 30.

Phidiaster KŒHLER, An Account of the Deep-Sea Asteroidea collected by Roy. Ind. Mar. Surv. Ship *Investigator*, Calcutta, April, 1909, p. 28. Type, *Phidiaster agassizi* Kœhler.

Diagnosis.—Disk small; rays five, high at base, tapering, pointed, with sides perpendicular or arched inward toward actinal surface; marginal plates massive, plane, not tumid, separated by fasciolar grooves, either shallow or fairly deep; superomarginals with or without large spinelets; inferomarginals regularly with several enlarged spinelets, either appressed to ray or bristling, and in the form of a perpendicular comb; exceptionally the inferomarginal spinules form two fairly regular longitudinal series along ray; abactinal area with compact paxillæ, arranged usually in regular transverse lines at sides of ray, and with polygonal or roundish bases; actinal interradial areas small, with numerous small intermediate plates which extend far along ray, and which bear compact groups of spinelets often subsacculate; papulæ absent from midradial area and center of disk; armature of adambulacral plates, a furrow series of rather long delicate cylindrical or flattened spinelets in a straight or slightly curved series and on actinal surface, about two longitudinal series of shorter more compressed spinelets, sometimes irregular in disposition; anus present or absent; well-developed superambulacrals; tube feet conical without sucking disks; no pedicellariæ.

Remarks.—This genus differs from the closely related *Bathybiaster* in having a rather numerous furrow series of slender subequal spinelets in a slightly curved comb, the outer edge of which is frequently straight; the central spinelet of series is not greatly enlarged, nor is the series very angular as in *Bathybiaster*. There is not a flap of integument at the tip of any spinelet, as typically the case with the central spinelet in *Bathybiaster*. Sometimes the actinal spines are nearly as sacculate as in *Bathybiaster*, but the marginal spines are much more prominent in *Psilaster*. In *Bathybiaster* the base of a paxilla is stellate; in *Psilaster* roundish or polygonal.

PSILASTER PECTINATUS (Fisher).

Pl. 7, figs. 5, 7; pl. 10, figs. 1–3; pl. 50, figs. 3, 3*a–c*.

Bathybiaster pectinatus Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 295.

Plutonaster abyssicola Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, July 17, 1905, p. 30, pl. 3, figs. 13, 14; pl. 19, figs. 102–106.

Diagnosis.[a]—Rays five. $R=73$ mm.; $r=15.5$ mm.; $R=4.7$ r. Breadth of ray at base, between first and second superomarginals, 16 mm.; midway along ray, 13.5 mm. Rays moderately elongate, tapering continuously from base to a sharply pointed extremity; interbrachial angles rounded; lateral wall, formed by marginal plates, nearly vertical, or sloping inward toward the actinal surface, only the upper end of the superomarginal plates forming a narrow border to paxillar area; abactinal surface slightly inflated on disk usually plane on rays; actinal surface convex; a low epiproctal cone usually present; a very small anal aperture. Paxillæ of abactinal area small, not crowded, with about four central stubby spinelets surrounded by a peripheral series of ten to fifteen slender ones. Superomarginal plates each with a sharp spinule near upper end, on edge of ray, forming a series for two-thirds or three-fourths length of arm; sometimes two such spinules present; inferomarginals with two spinules, one above the other, the upper forming a series to tip of ray, the lower a parallel series for only about two-thirds length of ray. Adambulacral plates with a furrow series of eight spinelets (seven in small specimens) and on actinal surface two or three longitudinal series of three or four each, invested in a pulpy saccular sheath. Actinal intermediate areas small, the plates beset with compact groups of very fleshy, spatulate, round-tipped papillæ.

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[a] From type; important variations exhibited by other specimens are mentioned, however.

Description.—Paxillæ of abactinal surface small, not crowded except at center of disk; arranged in transverse rows at sides of the paxillar area of rays; five or six such series corresponding to two inferomarginals at base of the rays; no definite arrangement along median radial line, nor in central portion of disk; size of paxillæ decreasing toward extremity of rays, and on the disk, toward center; on the rays the largest are along midradial line, and on disk about midway between center and edge. Each paxilla consists of a compact, flat-topped, subcircular or irregularly elliptical group of small, cylindrical, round-tipped membrane-invested spinelets, of which two, three, four, or five (on larger paxillæ) are stouter and occupy the center of tabulum, being closely surrounded by ten to fifteen slenderer spinelets, which frequently have the membrane thinner. Small papulæ are visible in the spaces between the paxillæ, especially on rays.

The abactinal plates or bases of paxillæ (viewed from inner or cœlomic surface of abactinal integument) are generally circular in outline except on outer half of ray, where they are longitudinally elliptical, and in center of disk and along midradial line, where they are often slightly irregular. The plates are spaced, and are much closer together in center of disk and along median radial line, where there are no papulæ, than along sides of abactinal area. On the latter areas they are arranged in very regular transverse rows which assume an interradial direction on disk, and the plates increase in size toward the midradial line, where for a width of about three plates there are no papulæ and no regular arrangement of plates. The plates decrease in size toward center of disk. The papulæ are single and so arranged that there are usually six about each plate of the papular areas. The area without papulæ in center of disk has a radius less than one-third distance from center to edge of paxillar area.

Superomarginal plates, forty-six in number, from median interradial line to extremity of ray, are nearly vertical in position, the upper ends forming a narrow border to paxillar area. In some specimens the plates slope inward toward the lower end so that the greater part of the plate can be seen from actinal side. Plates are about two-thirds as long as high, very regular, with curved upper end, and are covered with small squamiform spinelets or granules along the median transverse or vertical line, these becoming slenderer and more papilliform toward the edges of the plate, especially in the deep fasciolar grooves, where they are capilliform. At about 1 mm. from upper end of the plate is an erect, slightly flattened, sharp spinule attaining a length of 1 to 1.25 mm., and decreasing in length toward extremity of ray. On first two or three plates they are much reduced in size. They form a regular longitudinal series at border of the abactinal surface, extending two-thirds to three-fourths length of ray. In typical specimens an occasional plate has a second spinule below the first, and rarely three in a vertical series. Several specimens from station 3308 have two spinules on nearly all the plates except in the interradial angle (where the single spinule is not reduced in size) and toward the outer end of series. Similarly, three spinules occur on a number of inferomarginals, so that a side view of ray shows four or five spinules in a vertical series.

Inferomarginals correspond exactly to superomarginals in number and length, the line separating the two series being straight; plates slope inward, but the exposed surface is strongly arched, forming a rounded margin to actinal surface, the latter passing gradually into the lateral face of ray. The dorsolateral margin, on the other hand, is very abrupt. Plates are covered with squamiform, broadly lanceolate, ovate, obovate, blunt, or often sharp spinelets, which increase in size toward lower end of plate, but are very slender and terete in the fasciolar grooves. About 1 mm. from the upper end of each plate is a flattened slender tapering spine, attaining a length of 3.5 mm., the series of which extends the length of the ray, being absent occasionally from the first one to three plates. These spines or spinules either stand out from side of ray or are frequently appressed against it and may be equal to or longer than superomarginal spinules. Spaced from the above spinule, about midway between its base and lower end of plate, is a second similar but shorter spinule, forming on the plate a vertical series, and a longitudinal series for about two-thirds the length of ray. Some specimens have a few plates with three spinelets in a vertical series. All the spinelets covering the marginal plates are sheathed by membrane, which in alcoholic specimens causes these spinelets to appear very compactly placed, with broad rounded tips. When the specimen is dried the squamiform spinelets are seen to have narrower rough tips and to be distinctly spaced. Terminal plate a trifle wider than long, rounded distally, concave next to paxillar area, where three rows of paxillæ touch its free edge. The granuliform covering is rubbed off.

Adambulacral plates with a prominent angular margin to furrow. Armature consisting of (1) furrow series of eight (seven in some specimens) delicate subequal, membrane-invested, round-tipped spinelets, the two or three at either end of series flattened with sides to furrow, while the four or two central spinelets have the edge to furrow; the lateralmost spinelets are often shorter than the others; (2) on the actinal surface are two or three longitudinal series of flattened, truncate or round-tipped spinelets, four or five to each series. The outer spinelets are slightly wider than the inner and all are subequal to furrow series. Actinal spinelets are sheathed in a thick pulpy membrane which gives them a papilliform clavate appearance. In dried specimens the spinelet is seen to be slenderer, but flattened, with a rounded tip often wider than base. The first and second adambulacral plates are much compressed, and each has two transverse series of spinelets, about twenty to twenty-four on the first plate and about sixteen on the second.

Mouth plates elongated in the interradial direction, narrow, the median suture being dilated near the middle. The spinelets are arranged in two parallel series on each plate. The marginal series consists of about fifteen to eighteen short, regular, slightly flattened spinelets, decreasing in length at outer end of plate, but subequal all along inner half. These spinelets stand close together and are appressed against a superficial series of about the same number of heavier, cylindrical, subglobose or clavate skin-covered spinelets, which increase in thickness toward the outer end of plate. The inner end of the combined pair of plates is truncate, and either two or four spinelets at the angle are slightly larger and heavier than the others, are slightly bent at base, and are appressed against innermost of the superficial spinelets. Typically the spinelets are very regular in arrangement, the superficial series of companion plates being close together in some examples, in others separated by a conspicuous furrow. The armature of mouth plates is set at a considerably higher level when animal is viewed from actinal side than is that of the adambulacral plates; that is, the plates are very prominent.

Actinal interradial areas small, the plates extending to twentieth or twenty-second inferomarginal; or a little less to a little more than two-thirds length of ray. The plates adjacent to adambulacrals are largest, and the arrangement is in irregular rows between the adambulacral and inferomarginal plates, there being more or less variation in details.[a] In the Californian specimens, which are smaller than Ludwig's material (from Gulf of Panama), the plates on the ray are not so regular as in his figure 102, there seldom being two intermediate plates of the external series corresponding to one in the series adjacent to adambulacrals. Usually there is but one. The difference in size may account for this. The plates are beset with compact groups of very fleshy spatulate round-tipped papillæ, which become pressed into various shapes by mutual contact. The calcareous spinelet within the papilla is delicate, subcylindrical, truncated, sometimes flattened at tip. The number of papillæ to each plate varies, and they are so compactly arranged that if the prevalent slime is thoroughly cleaned off, the outlines of the groups in the interradial areas are clearly distinguishable. At the outer end of the mouth plates are a few isolated papillæ resembling in shape a flattened grain of corn attached by the small end. In *Bathybiaster pallidus* Danielssen and Koren describe such groups of spinelets as pedicellariæ. In the present species although the compact grouping may suggest pedicellariæ, it is not at all likely that the spinelets subserve any such function. Structurally they are no more to be considered as pedicellariæ than are ordinary paxillæ.

Madreporic body small, broadly oval, situated a little to the outer side of a point midway between center and margin of disk. Striations coarse and interrupted, radiating from the adcentral side of plate. The ridges are occasionally branched.

Anatomical notes.—Superambulacral plates well developed, but absent from first two ambulacral plates and from about the last twelve which are small and crowded against marginals. All except the two first superambulacrals extend from the ambulacrals to upper end of inner surface of inferomarginals. The first two meet the actinal intermediate plates. This varies probably with the size of the specimen. A very small anal opening is present to which a short intestine leads from the dorsal stomach. On the side of the intestine toward madreporic canal, and on the opposite side (toward anterior ray) is a digitate saccular intestinal cœcum which varies in shape in different individuals. In one example the cœca have short very irregular branches, and in another four and five regular divisions, respectively, the latter resembling glove fingers. Gonads in a tuft on either side of interradial line, the aperature of each about 2 mm. from marginal plates in the abactinal integument. Polian vesicles six, one on either side of madreporic canal, and one in each of the other four interadii. Interradial septa uncalcified.

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[a] See Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, 1905, pl. 19, fig. 106.

Variations.—Certain variations due to size are shown in the following table:

Table showing variations in Psilaster pectinatus.

Station.	R.	r.	R : r.	Breadth of ray at base.	Number of superomarginal plates.	Number of superomarginal spines.	Number of inferomarginal spines.
3308	16	6.5	2.46 : 1	7	20	1	1
3308	29	10.0	2.9 : 1	10.5	27	1	2 or 1
3308	53	13.0	4 : 1	15.0	38	1 or 2	3 to 1
3308	71	16.0	4.3 : 1	19.0	47	1, rarely 2	3 to 1
4387	73	15.5	4.7 : 1	17.5	46	1	2 or 1
3306	84	17.0	5 : 1	17.5	58	2 or 1	3 to 1

The greater number of specimens examined are from Bering Sea. Among these the chief variations are in proportions, including length and width of ray relative to disk; in the amount of inflation of abactinal integument; relative size of epiproctal elevation; number of superomarginal spinules; the degree which the exposed surface of marginal plates, or in other words the side wall of ray, departs from the perpendicular; adambulacral spinelets of furrow series are seven or eight; slight difference in size of actinal interradial areas; the tenuity of extremity of rays; compactness of actinal intermediate paxillæ. There is also a trifling variation in the size of paxillæ of abactinal area; as a whole the specimens are remarkably uniform in this character.

Unfortunately there are only three adult specimens from off southern California. These are pretty much alike. One specimen has a narrower paxillar area on rays, but a larger disk and larger paxillæ than have the other two. Compared with specimens from Bering Sea, these examples present no important differences. The rays are a trifle thicker dorsoventrally, and the sides are a little higher in consequence. The marginal plates are more vertical in the southern specimens than in those from Bering Sea, where the side wall of ray generally slopes inward on the actinal surface. But many from the latter locality have the side wall nearly vertical. There are not enough southern specimens to determine whether the presence of a second superomarginal spinule is more frequent in the northern individuals. The marginal spinules sometimes stand out at an angle from ray, but are more often tightly appressed to side; this difference changes the general facies in a misleading manner. Smaller specimens as a rule have the rays thicker near the tips than the large examples.

All the variations appear to be of slight importance—that is, are such as may be expected in starfish species—and the Alaskan examples belong, seemingly, to the same species as the California specimens. The latter show no important differences from Panamic examples described by Ludwig under the name *Plutonaster abyssicola*.

Young.—Young examples have much shorter, blunter, and distally thicker rays than adults and half-grown specimens, the difference in proportions having been given in the foregoing table. The marginal plates are more prominent on the abactinal surface; each plate of both series (except near tip of ray of superomarginal series) bears a single spinule. The adambulacral plates have five to seven furrow spinelets. Actinal interradial areas are smaller than in large examples, the plates extending about one-half length of ray. Both the upper and lower edge of ray is rather abrupt, not the upper alone as in adults. The epiprictal cone is scarcely more prominent than in adult.

Type.—Cat. No. 22327, U.S.N.M.

Type-locality.—*Albatross* station 4387, off San Diego and southeast of San Clemente Island, California; 1,059 fathoms, mud.

Distribution.—Bering Sea to Bay of Panama,[a] in 1,033 to 1,625 fathoms, on green ooze, green mud, sand, and hard bottom.

Specimens examined.—Total number, one hundred and nineteen, from the following stations; six specimens have no label.

Specimens of Psilaster pectinatus examined.

Station.	Locality.	Depth. *Fathoms.*	Nature of bottom.	Number.	Collection.
3307	Bering Sea, northwest of Umnak Island	1,033	green ooze	29	U S. Nat. Mus.
3308	Bering Sea, west of Pribilof Islands	1,625	do	47	Do.
3604	Bering Sea, south of St. George Island	1,401	do	1	Do.
3601	do	1,044	green mud, fine sand	32	Do.
4387	Off San Diego, California	1,059	mud	4	*Albatross*, 1904.

Remarks.—This species has the general appearance of a long-spined *Bathybiaster*, but the character of the abactinal plates, adambulacral armature, and rather deep marginal fascioles assigns it to *Psilaster*. The double row of inferomarginal and single row of superomarginal spines is very similar to the arrangement of the much smaller spinelets in *Bathybiaster*, and the actinal spinulation is decidedly sacculate. It was these considerations which led me to describe the species under *Bathybiaster*. Since then, however, I have seen an abundance of material of this species and have examined *Bathybiaster vexillifer* and *B. robustus*.

The character of the adambulacral armature is the most tangible feature which separates the two genera. Both may have sacculate actinal spinelets, but *Psilaster* has not the very angular furrow series with an elongate median spine bearing, sometimes, a terminal flap of integument. The marginal spinules of *Bathybiaster* are very inconspicuous and the vertical fascioles along the suture between the plates are decidedly shallow.

Ludwig classifies this species in *Plutonaster*, a course which seems to me wholly untenable, since it must necessarily ignore the sum of the structural characters in favor of the presence of an anus. This is a good example of the bizarre results which follow adherence to the erroneous idea that Astropectinidæ lack and "Archasteridæ" possess an anus. It is also an instance of the fact that the presence or absence of an anus is not even of generic value. It does not seem logical to ignore all of a half-dozen important skeletal and anatomical features in favor of a single oft disqualified character.

This species is readily distinguished from those described by Sladen, by the presence of one or two prominent superomarginal spines forming a regular series all along the upper edge of the ray, and by the fact that the bristling inferomarginal spines form about two longitudinal rows along at least two-thirds length of ray, and one row along the outer third.

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[a] *Plutonaster abyssicola*=*Psilaster pectinatus*.

Kœhler [a] has described the genus *Phidiaster* (Nicobar Islands, 888–930 fathoms), which is distinguished from *Psilaster* by the great development of the superomarginals. These plates, as well as the inferomarginals, carry each two large robust spines, forming thus four longitudinal series along the ray, one dorsal, one ventral, and two lateral. Another character is the presence on the inner angle of each mouth plate of two enlarged teeth.

In some respects *Psilaster pectinatus* is intermediate between *Psilaster* and *Phidiaster*. It has the superomarginal plates sufficiently large to satisfy the qualifications of *Phidiaster*, but has only one superomarginal series of spines, and the lower of the two inferomarginal series extends only part way along the ray. The teeth are not conspicuously enlarged. The characters of *Phidiaster* appear to be somewhat trivial for generic value. The superomarginal spines vary in the genus *Persephonaster*, being absent in the species formerly ranged under *Psilasteropsis*. Kœhler has, himself, called attention to the fact that the presence or absence of superomarginal spines can not be regarded as of generic importance in *Persephonaster*. Certainly the same remark applies equally well to the nearly related *Psilaster* and *Astropecten*. The superomarginals of *Phidiaster*, judging by plate 9, fig. 3 (Kœhler, 1909), are not larger than in *Psilaster pectinatus*, and some other species, as, for example, *Psilaster floræ* (Verrill). The superomarginals of *Astropecten* vary greatly in relative size, and I have seen enough species of *Persephonaster* to know that they do also in that genus. The remaining character, that of the teeth, is not shared by typical *Psilaster*, although there are two (instead of four) more or less enlarged median teeth at each mouth angle. These, in *Psilaster*, are usually bent up and not directed across the actinostome as in *Phidiaster*. From an analysis of these characters and owing to the intermediate position of *Psilaster pectinatus* I am inclined to unite *Phidiaster* with *Psilaster*.

Genus THRISSACANTHIAS Fisher.

Thrissacanthias FISHER, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 171. Type, *Persephonaster penicillatus* Fisher.

Diagnosis.—Near *Persephonaster* Alcock, but differing in the arrangement of gonads which are not confined to the interradii but extend for a short distance along the ray as a number of separate tufts depending from the genital rachis; adambulacral plates with one or two enlarged actinal spines; disk of medium size, depressed, rays long; marginals opposite, with conspicuous spines; abactinal surface with true paxillæ arranged in regular oblique transverse rows; no enlarged radial series; papulæ all over abactinal surface except at tip of ray; actinal intermediate plates extending far along ray; interradial areas rather small; spiniform fascicular pedicellariæ on marginals; anus present; madreporic body large, not hidden.

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[a] Deep Sea Asteroidea of the *Investigator*, 1909, p. 28, pl. 9, figs. 1, 2, 3.

THRISSACANTHIAS PENICILLATUS (Fisher).

Pl. 17, fig. 4; pl. 18, figs. 1–5; pl. 53, figs. 1, 1*a*–*e*.

Persephonaster penicillatus FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 297.

Diagnosis.—Rays five. R=176 mm.; r=35 mm.; R=5r. Breadth of ray at base (between second and third superomarginals) 36 mm. General form flattened; rays long, tapering from a narrow base and in small to medium-sized specimens swollen a trifle above base; disk rather small, capable of slight inflation; interbrachial angles rounded; abactinal integument thin, a trifle convex at base of ray. Paxillæ small, arranged in transverse spaced rows except on center of disk and along midradial line, each with a cylindrical pedicel crowned with a brush-like group of eight to twelve slender needle-like spinelets which are longer than pedicel; papulæ everywhere except at tip of ray, conspicuous. Superomarginal plates thirty-nine, strongly tumid, with a long, stout, tapering spine (sometimes two) in center, and one or two smaller spines on upper edge; large spines sometimes bifid; general surface of plate bristling with small spinelets; usually one or two pedicellariæ present, formed of two to four small sharp spinelets in a circle, these very inconspicuous and sometimes absent; occasionally present on inferomarginals. Latter are opposite superomarginals; a few of proximal plates with a transverse series of three stout tapering pointed spines, sometimes, but not always, a trifle flattened and bifid; rest of plates including first two with two such spines; general surface bristling with delicate spaced spinelets, increasing in size toward lower end of plate and summit of transverse ridge; no true marginal fasciolar grooves; instead plates slope up gradually from sutures without forming abrupt specialized ridges, as in *Astropecten*, *Psilaster*, and others. Adambulacral plates with five or six (in smaller specimens three or four) furrow spinelets rather delicate and compressed, and forming a divergent palmate series, and on actinal surface an enlarged usually flattened blunt spine with a variable number of smaller blunt membrane-invested spinelets surrounding it or in two longitudinal rows. Mouth plates with peculiar furrow series formed of an angular group of about five spinelets situated at a higher level than enlarged tooth; that is, nearer peristome. Actinal interradial areas small but plates extending far along ray, and armed with rather delicate spaced spinelets, these sometimes forming a pedicellarian apparatus. Madreporic body large, free; gonads in several tufts (ten to twelve) extending a short distance along ray; superambulacral plates very well developed.

Description.—The rays are decidedly long in this species and longer in large than in small specimens. Abactinal integument thin, frequently collapsed on outer part of ray onto the ambulacral ridge. Paxillæ small to medium sized, distinctly and uniformly spaced; arranged in transverse well-spaced series on rays, but without regular order in center of disk and along midradial line. The paxillæ decrease regularly in size distad and toward center of disk, and not so conspicuously toward marginal plates, being largest on the radial areas at base of ray. The transverse rows of paxillæ are quite regular, and between them is a double row of conspicuous papulæ. Each paxilla consists of an elongate, elliptical base set longitudinally with reference to long axis of ray, surmounted by a stout, cylindrical, convex-tipped pedicel which bears a crown of eight to twelve (type) very slender, tapering needle-like spinelets, considerably longer than the pedicel, and usually standing upright in a cylindrical coordinate group, highly characteristic. Paxillæ in center of disk have irregular or circular bases. Small paxillæ are scattered here and there on the radial areas with only three or four spinelets. In some specimens the spinelets are thicker, due to the investing membrane. On the distal portion of ray the tabulum or pedicel of paxillæ becomes gradually much shorter, and at tip of ray the paxillæ are convex spine-bearing plates. There is some variation in the diameter of the paxillæ but all specimens agree in having the characteristic arrangement in transverse spaced rows. On an average three transverse series correspond to one superomarginal plate. The paxillæ resemble, frequently, pseudopedicellariæ from the fact that the spinelets all converge and meet at one point, forming a conical group.

The abactinal plates viewed from inner surface of dorsal integument are very regular on the areas of regular paxillæ, where, as mentioned above, they are elliptical in general form, with a suggestion of a lobe at either side in medium sized and small individuals. In large examples the plates are very distinctly spaced all over the dorsal surface, but in medium-sized specimens they usually touch, at least in center of disk and along radial areas. The regularity of the plates is broken on these areas; along the latter the plates become shorter and broader, often irregular, while on the disk they are subcircular. The difference in appearance of the abactinal plates in large and medium-sized examples seems to be due to the fact that beyond a certain stage the paxillæ do not increase in numbers in proportion to the increase in size of the individual. Thus, an example with R=96 mm. has a width of ray at third superomarginal of 22 mm. and twenty-seven to twenty-nine paxillæ in a row across the ray. The type, with R=176 mm., and a breadth of ray at third superomarginal of 36 mm. has only thirty-two to thirty-six paxillæ. As a result the paxillæ are much more widely spaced in large specimens. The papulæ are very conspicuous, and are distributed everywhere except at very end of ray. The regular arrangement in double transverse rows is interrupted along radial line and at center of disk, but papulæ are present in these regions. In many specimens the papulæ are as large as the paxillæ in diameter.

Superomarginal plates, thirty-nine in number from interradial line, very tumid, and not usually encroaching very conspicuously onto abactinal area proximally of the middle of ray. Beyond this point the plates encroach more and more onto abactinal surface, until considerably more of the plate belongs to the upper surface than to side. Plates are subquadrate, except in interbrachial arc, where they are much higher than long; abactinal margin of plates slightly rounded. There are no fasciolar channels, but only a vestige of them, the surface sloping gradually from the sutures toward the middle of the plate which bears a robust tapering spine (or occasionally two), much longer than the plate (7 or 8 mm.) and directed obliquely upward and outward. These spines are longest at about middle third of ray, thence decreasing very gradually in length toward tip of ray. Many of them are very curiously bifid for half or two-thirds their length, as if composed of two fused spines, and, therefore, possessing two closely appressed points. Abactinal margin of plate bears one or two robust, upright, tapering, pointed spinules or spines

(2 to 3.5 mm. long). When two are present, the adoral is commonly shorter; in some examples these spinules are very short, scarcely more than 1 mm. General surface of the plate bristles with very slender spaced capillary spinelets, largest near the spines, these becoming papilliform in some specimens on account of a pulpy membranous sheath. They are shorter than adjacent paxillar spinelets. Near each upper corner of nearly all the superomarginal plates of type is a small pedicellaria composed of usually four or five (sometimes only two or three) short sharp spinelets, stouter than the rest, arranged in a circle about a common center, or they may be more like the pectinate form characteristic of *Cheiraster*. The position and number of these varies in different specimens. Sometimes there is but one, near the upper marginal spine, and in specimens from the northern part of range the pedicellariæ are few, and many of the plates do not have any. In a small specimen (young) from station 2923 they are very conspicuous. Similar pedicellariæ occur less frequently on the inferomarginals, usually near or on the intermarginal suture.

Inferomarginal plates corresponding in number to superomarginals, to which they are opposite, forming a steep slightly arched bevel to actinal area. They are also tumid, especially along the transverse axis, the tumidity passing into the corresponding superomarginal without any conspicuous break at the suture between the two. A few of the proximal plates bear a transverse series of three stout, tapering, pointed spines, frequently a trifle flattened and bifid like those of upper series; the rest of the plates, including usually also the first two, bear two such spines, the upper the longer (8 to 9 mm.). Rarely on distal part of ray, where the lower spine is occasionally much reduced in size, there may be either three or four spines, due chiefly to the fact that a spine is split to its base, being in reality two spines with a common articulating boss. These spines are all commonly appressed to ray as in *Psilaster*. General surface of plates bristles with delicate spaced spinelets, which increase in size toward lower end of plates and toward summit of tumidity. Pedicellariæ, as described above, are occasionally present. Terminal plate with apparently two spines.

Adambulacral plates set obliquely, broader than long at base of ray and longer than broad near tip; furrow margin curved. Armature consisting of (1) a furrow series of five, or less commonly, six (type) compressed, rather delicate, slightly curved, blunt skin-covered spinelets, often capped with a knobby membranous tip, arranged palmately, and usually graduated in length from the adoral to the aboral end of series, or they may be graduated from the middle or the second spinelets. There is considerable variation even in the same specimen in the number of furrow spinelets. Some specimens have three or four; and the diameter of spinelets varies according to the thickness of the investing membrane; (2) on actinal surface of plate is an enlarged flattened blunt spine frequently with a shallow groove running from tip half way to base, this surrounded by a variable number of smaller, tapering, blunt or pointed skin-covered spinelets, arranged frequently in two longitudinal rows, three or four to each, the spine standing in the inner series, or between the two, in which case the spinelets appear to form a wide circle around it; outer spinelets usually much flattened at tip and furrowed lengthwise as if incipiently bifid. Rarely a second spinule accompanies the enlarged spine, or none of the spinelets may be flattened or furrowed, but tapering and fairly sharp, in which case none of the marginal spines are flattened and bifid. Some (northern) specimens have the enlarged "spine" very inconspicuous and only slightly larger than the other spinelets. In small specimens there are but two or three actinal spinelets in addition to the spinule. Adambulacral armature is extremely variable, both according to size and locality.

Mouth plates elongate, narrow, prominent actinally; interradial length 13 mm.; width of combined plates 5 mm. At inner angle of combined plates are two stout enlarged, somewhat curved, blunt spines, and the whole surface of the plates is covered with short thick, blunt, very robust spinelets, which are largest near the inner angle and decrease in size and thickness toward the margin adjacent to first adambulacral. Furrow series very angular, and consisting of a group of spinelets, about six in number, situated at a higher level than the tooth, and continued to first adambulacral along the excavated short free margin in about four more short pointed spinelets. The two actinal spines adjacent to teeth may be nearly as large as the latter, making four teeth at angle, and one of the true furrow spinelets is occasionally enlarged. In some specimens there is a regular and prominent series or double series along the margin of the median suture, with a few slenderer spinelets along the sides, lower down, the actinal surface of plates being very convex. The first adambulacral forms a short but wide companion plate, being much compressed.

Actinal interradial areas rather small; intermediate plates small on rays, larger on disk, extending in a single series 0.75 to 0.8 length of ray measured along side; a second series extends 0.5 to 0.6 as far as first; a third about 0.25 to 0.33 as far as the second (to the third to sixth inferomarginal). Large specimens have seven or eight plates in an interradial series opposite first inferomarginal. Superficially the plates appear roundish and much as in *Psilaster*, *Bathybiaster*, and allied forms. Viewed from the inner side, the plates are seen to imbricate slightly, and are a trifle tumid and armed with a group of rather delicate, often flattened, obtuse, grooved, occasionally bifid spinelets, similar near adambulacral plates to their outer actinal spinelets, and forming thence all the transitions between these and the lower spinelets of the inferomarginals. These spinelets are all sheathed in membrane, which is frequently swollen at the tip; in some specimens the spinelets have a papilliform appearance, and the calcareous part is slender and needle-like without flattening or grooving. Not infrequently a central spinelet is enlarged, and on some of the plates near the adambulacrals four or five spinelets form a circular group, suggesting a sort of pedicellarian apparatus.

Madreporic body large (7 mm. in diameter), entirely uncovered, circular to irregularly oval, the inner edge being about at the midddle of minor radius.

Color in life, madder brown.

Anatomical notes.—Very well developed superambulacral ossicles are present; these are absent from first four plates and rudimentary near tip of ray. The gonads are not confined to the interradial region but extend a slight distance along ray, there being ten to twelve independent clusters of tubules depending from each side of a ray, forming a linear series. The genital stolon to which they are attached is easily seen. Each cluster is composed of a single tube divided at base into two or three long branches, the latter being subdivided into many, thick, irregular, often grotesque side branchlets or pockets. Anal aperture present, connecting with a large saccular intestinal cœcum. Viewed from above this cœcum is shaped like a butterfly with rounded wings, there being a deep sinus in the outline, in the interradius to right of madreporic body, and another shallower one in the left radius of trivium (corresponding to anterior and posterior ends of butterfly). This cœcum is connected with spacious stomach by good-sized intestine. Tiedemann organs small; Polian vesicles, one in each interradius. Tube feet pointed, without calcareous deposits; ampullæ double. Interradial septa membranous.

Variations.—The principal variations have already been alluded to in the foregoing description. These concern the number and relative thickness of paxillæ spinelets; the relative size of the spinelets on upper edge of superomarginals, these being usually smaller and two in number in northern specimens, frequently only one in southern examples; the minute spinelets covering superomarginals, and the number of pedicellariæ, the former being thicker and the latter fewer in northern examples, and more conspicuous in young than in very large specimens; the shape of marginal spines, these being more often flattened and bifid in southern specimens, and more often needle like in northern, the general appearance of actinal spinulation, this varying from slender to papilliform, but never crowded; the number of adambulacral spines and spinelets; mouth plates and their armature. Some specimens have slightly wider and shorter rays than the type but the variation in this respect is inconsiderable.

Young.—The smallest specimen, from station 2923, has R=31 mm., r=7 mm., and most of the adult characters well developed. The paxillæ are fewer, but in proportion to size of specimen are larger than in adult. They have eight or ten spinelets, occasionally more. Marginal pedicellariæ conspicuous; actinal intermediate plates fewer than in adult. The general appearance is unmistakable after one knows the adult form, but the superomarginals encroach conspicuously onto to abactinal area. The general facies of the marginals reminds one of *Cheiraster,* except for the fact that the plates of the two series correspond. The abactinal paxillæ and distribution of papulæ are very different from *Cheiraster.*

Type.—Cat. No. 22329, U.S.N.M.

Type-locality.—*Albatross* station 4380, off Los Coronados Islands, southwest of San Diego, California, 530 to 638 fathoms, gray sand, green mud.

Distribution.—Washington to Lower California (Los Coronados Islands) and from 277 to 822 fathoms. Usually on green mud or fine sand.

Specimens examined.—Thirty-four from the following stations:

Specimens of Thrissacanthias penicillatus examined.

Station.	Locality.	Depth. Fathoms.	Nature of bottom.	Number.	Collection.
2890....	Off Heceta Bank, Oregon..............	277	gray sand....................	3	U. S. Nat. Mus.
2923....	Off Point Loma, San Diego, California...	822	green mud....................	5	Do.
2936....	Off Point La Jolla, San Diego, California..	359	mud..........................	8	Do.
2979......	Off Anacapa Island, southern California..	388	green mud....................	2	Do.
3073......	Off Sea Lion Rock, Washington..........	477	.....do......................	2	Do.
3112......	Off Pigeon Point, California.............	296	fine gray sand................	2	Do.
3343....	Off Destruction Island, Washington.....	516	green mud....................	1	Do.
3347.....	Off Cascade Head, Oregon...............	345	mud..........................	2	Do.
3348......	Off Point Arena, northern California......	455	fine gray sand................	6	*Albatross*, 1904.
4351.....	Off San Diego, California................	161–510	fine gray sand, green mud, rocks.	1	Do.
4380....	Near Los Coronados Islands, Lower California.	530–638	gray sand, green mud.........	1	Do.
4427....	Off Santa Cruz Island, California.........	475–510	black mud, broken stones.....	1	Do.

Remarks.—This species was originally described under the genus *Persephonaster*, although I was uncertain of the identification at the time. The radically different arrangement of gonads which extend part way along the ray, on either side, and the presence of a large actinal adambulacral spine are the two important features which distinguish *Thrissacanthias* from *Persephonaster*.

Although the types of *Persephonaster* and *Psilasteropsis* have a different facies, an analysis of the characters of several species from Hawaii, the Philippines, and Japan seems to warrant uniting the two genera. Typical *Psilasteropsis* has narrow block-like inferomarginals which do not encroach far onto the actinal surface, while in typical *Persephonaster* the inferomarginals are somewhat wider actinally and the superomarginals possess stout spines. In other species of *Persephonaster* the inferomarginals encroach conspicuously onto the actinal surface and the superomarginal spine is small. The arrangement of gonads, general character of adambulacral armature, armature of inferomarginals, distribution of papulæ, armature of mouth plates (especially the angular marginal series and presence of two teeth at the inner angle of jaw), and arrangement of actinal intermediate plates are the same in the two genera. *Persephonaster* is the older name. (See also Kœhler, 1909*a*.)

Tritonaster is probably a specialized offshoot of *Persephonaster*, distinguished by the unusually small superomarginals, the very tumid inferomarginals (defining ambitus), and by the rudimentary actinal intermediate plates of the ray.

Blakiaster also resembles *Persephonaster*, but is distinguished by the presence of an odd interradial series of actinal intermediate plates, and lobed, imbricating, low, convex tabulate abactinal plates, simulating paxillæ.

In Japanese waters there is a species, yet undescribed, which resembles *penicillatus* in general appearance, but differs in several important and many minor details. This species has about three superomarginal spines in a transverse series; proximally four or five inferomarginal spines with several auxiliary spinules; distally three; a remarkable adambulacral armature consisting of a very angular furrow series of three small spinelets set high in furrow (as in *Henricia*) the true margin being occupied by four or five spinelets belonging to the first actinal series. The remainder of the surface is covered with a few spaced spinules one or two of which may be enlarged. This peculiarity of the true furrow spinelets is repeated in the furrow series of the mouth plates. In *penicillatus* the furrow spines of mouth plates are also situated high on the side of plate, which thus maintains an arrangement lost (or never acquired) by the adambulacral plates.

Genus DIPSACASTER Alcock.

Dipsacaster Alcock, Ann. and Mag. Nat. Hist., ser. 6, vol. 11, 1893, p. 87; Journ. Asiatic Soc. Bengal, vol. 62, 1893, p. 172 (no diagnosis). Type, *D. sladeni* Alcock.

Diagnosis.—Rays five. General form depressed with broad disk and well-developed actinal interradial areas; abactinal surface flat, not arched; marginal plates large, the inferomarginals always broader than superomarginals and typically extending laterally beyond them and forming a subserrate border to ray; fasciolar channels deep and conspicuous, the ridges being correspondingly highly developed; inferomarginals with a tuft of spines at outer end, or these may be exceptionally absent, the superomarginals sometimes with one to three small tubercles; covering of plates ranging from capillary spinelets to polygonal granules; paxilla highly characteristic, composed of a tall pedicel springing from a round or stellate base and crowned with a glomerular tuft of very many slender crowded spinelets; papulæ typically distributed all over the abactinal surface, in sixes or fives about the plates; no internal independent ossicles connecting plates; actinal intermediate plates carinated and imbricated, bearing a paxilliform group of spinelets, there being fasciolar channels leading from inferomarginals to adambulacrals; adambulacrals not compressed, with a palmate or pectinate furrow series of cylindrical or much compressed spines, and a variable number of smaller spinelets on exposed surface of plate, the latter usually not regularly arranged; mouth plates prominent actinally, rather broad, with numerous spinules on exposed surface, and a marginal series resembling those of adambulacrals; madreporic body typically very large, hidden by many large paxillæ springing from its surface. Anus always present, connected with an unbranched sac-like intestinal cœcum, lying in the left radius of trivium (or adjacent interradius of bivium), the latter connected with stomach by a short intestine; superambulacral plates always present; tube feet pointed, without calcareous deposits; gonads extending far along ray, the genital tubules depending from a genital stolon and decreasing in size distad.

KEY TO THE SPECIES OF DIPSACASTER HEREIN DESCRIBED.

a^1. Inferomarginal plates with a tuft of enlarged spines at outer end or a series along aboral margin; border of rays subserrate; papulæ distributed all over abactinal surface; madreporic plate very large bearing many paxillæ on its surface.

  b^1. Paxillæ conspicuously larger in central portion of disk and along median area of rays, their spinelets descending the pedicel in bristling array, so that they resemble minute bottle-brushes; rays broad near tips; abactinal plates strongly stellate along median radial area, with two or three papulæ to each area instead of one; actinal intermediate areas broad, far along ray......*eximius*, p. 86.

  b^2. Paxillæ not conspicuously larger in central portion of disk, etc., their spinelets grouped at top of pedicel; rays evenly tapered to tip; abactinal plates along median radial area either round or stellate, but not surrounded by many papulæ, never by more than eight; actinal intermediate areas narrow beyond middle of ray.

c^1. Abactinal plates lobed; marginals broader, covered with compact, rigid, polygonal granules (superomarginals) and squamæ (inferomarginals); superomarginals with one or two tubercles; adambulacral furrow spines compressed with broad side to furrow; actinal intermediate plates covered with squamiform spinelets..*borealis*, p. 91.

c^2. Abactinal plates not lobed; marginals narrower, the superomarginals without tubercles and covered with delicate capillary spinelets; inferomarginals with delicate imbricating narrow squamiform spinelets; adambulacral furrow spines strongly compressed with edge to furrow; actinal intermediate plates with slender spinelets..........................*lætmophilus*, p. 95.

a^2. Inferomarginals entirely without specialized spines; border of ray even, not serrate from the form of inferomarginals; papulæ absent from center of disk; madreporic plate median sized, hidden, but with only one or two paxillæ on its surface....................................*anoplus*, p. 97.

DIPSACASTER EXIMIUS Fisher.

Pl. 11, figs. 1, 2; pl. 13, fig. 2; pl. 14, fig. 1; pl. 16, fig. 3; pl. 52, figs. 1, 1*a–c*.

Dipsacaster eximius FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 296; Zool. Anz., vol. 35, March 29, 1910, p. 546.

Diagnosis.[a]—Rays five. R=124 mm.; r=55 mm.; R=2.26 r. Breadth of ray at base, 60 to 65 mm.; at middle of ray, 46 mm. General form flattened, rays broad, leaf-like in shape, tapering gradually, but with an outwardly curved contour; extremity bluntly pointed; interbrachial angles wide, abruptly rounded; abactinal surface but slightly inflated, a slight depression on interradial lines; actinal surface subplane. Abactinal paxillæ very regularly arranged in chevrons, largest along midradial area and center of disk; each with a large tuft of very numerous slender spinelets which extend down pedicel for half its length, or more; regular arrangement interrupted on area of largest paxillæ. Papulæ generally distributed, six around each lobed plate, except along radial line where there are two or three papulæ to each area, and twelve to twenty about many of the plates. Marginal plates massive, the inferomarginals defining contour of ray, and armed on outer end with a transverse or vertical row of four to six short stout tubercles; superomarginals usually with a single short tubercle; occasionally more. Adambulacral plates with five or six strong furrow spines, the median longest and all more or less compressed, with edge uppermost; and on actinal surface two or three rows of three or four spinelets each; usually only the inner actinal row has any regularity. Actinal intermediate areas large, and maintaining a considerable breadth far along ray; intermediate plates strongly carinated bearing a cluster of spinelets of which the peripheral are slenderest, those in center not typically much enlarged although occasionally so on some specimens.

Description.—The rays in this species have in large examples, a very characteristic broad leaf-shape. That is, they taper only slightly from base to outer third, thence the edges curve and taper rapidly to the blunt extremity. Paxillæ large; largest in center of disk and along median radial areas, thence decreasing gradually and uniformly in size toward the marginal plates. They are very regularly arranged in oblique transverse rows along either side of the median radial area, forming chevrons pointing toward center of disk; but on latter area and along radial line the paxillæ, due to their becoming larger, have no regular arrangement. Opposite or corresponding to first four superomarginals, in large specimens, are eight to ten transverse rows of paxillæ. Each paxilla springs from a lobed plate (described below), the shaft with spinelets being 3.5 to 6 mm. high in larger specimens. This shaft or pedicel is surmounted by a globular or elongate crown of very numerous, slender spinelets sheathed in delicate membrane, the whole forming a dense glomerular tuft, the central or uppermost spinelets bluntly tipped, but those on the side mucronate, less crowded, and usually extending in a bristling arrangement down the sides of pedicel, for nearly to over one-half its length. In the latter case the paxilla resembles a minature bottle-brush. In a dried specimen the centrally situated spinelets are much sharper, due to a shrinkage in the membranous envelope.

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[a] From a large specimen from station 3112.

The abactinal plates or bases of paxillæ are strongly lobed on center of disk and along median radial area, the lobes becoming less prominent toward margin of abactinal area. Some plates have six, some four, some five lobes, and they are very irregular. On the regular lateral rows of plates there is more uniformity, but here some plates have five divisions while the majority have four. Near center of disk numerous plates are rounded or irregular without evident divisions. In another specimen examined the plates are much more regular especially along the lateral rows. Here they touch or slightly overlap by lateral lobes, which does not take place in the first example. Some plates near the margin of interradial area are nearly square. Papulæ are distributed all over abactinal paxillar area, from tip of ray to center of disk. There are usually six about each plate, but where the plates are not arranged in regular rows there are often more, especially in the case of the median radial series. When viewed from the outer surface, the papular areas are seen to be larger here, and to contain two or three papulæ, instead of one, as is usual. Thus a carinal or radial plate may be surrounded by twelve to eighteen or twenty papulæ in groups of two or three, these papulæ being of course common also to several adjacent plates.

Marginal plates massive and regular, the inferomarginals defining contour of ray, and extending laterally beyond superomarginals for a variable distance which is sometimes (as in type) equal to width of latter. Superomarginals, over thirty (thirty-two to thirty-four) in large specimens, are slightly wider than long, and shorter in proportion to width in interbrachial angle than farther along ray. They are completely confined to abactinal surface, and form an arched bevel to margin of paxillar area. The exposed surface which is slightly tumid, is covered with small but robust polygonal flat-topped spinelets in middle, these rapidly becoming slenderer toward edge of elevated ridge, where they are either blunt or sharp; and are longer on outer than on inner edge of plate. Nearly all the plates bear a tubercular, short, polygonal stumpy spine either near middle or in outer aboral quarter of plate. In some specimens there is a group of two or three such tubercles, which do not extend conspicuously above the general covering of plate, except in rare cases, but are larger on outer part of ray than on proxinal portion.

Inferomarginals correspond exactly to superomarginals, are much wider than long, and form a conspicuous border to actinal surface. On outer end of each plate (or rather the specialized ridges) is a transverse series of four to six stout tubercular spines the upper or next to upper longest, forming an armature on margin of ray. In some specimens (usually small to medium-sized) these spines are tapering and rather sharp, but usually on large examples are truncate and thicker at tip than at base; and the tip is also usually truncated obliquely, due to the spines being bent toward tip of ray. Near base of ray the thick spines may have the tip curiously hollowed out like a cup, instead of being cut square off or slightly rounded. General covering of plate consists, on actinal surface, of ovate or oblong lanceolate spinelets, which become capillary in fasciolar furrows; outer end of plate bristles with slender, sharper lancet-like spinelets those on sides of the broad fasciolar grooves, frequently with fine mucronate tips. Spinelets adjacent to the spines are enlarged. The fasciolar grooves between plates are very deep, the specialized ridges being about as thick, when denuded, as the adjacent grooves. These ridges, when viewed from actinal surface, extend laterally beyond the bottom of groove a distance equal to the width of the plate, measured from bottom of groove to inner (actinal) edge.

Terminal plate small, granulous, as wide or wider than long, not notched toward paxillar area.

Adambulacral plates fairly massive with a curved furrow margin. Armature consists of (1) a furrow series of six strongly compressed, round-tipped spines, the two centrally situated the longest (3.75 to 4 mm.) and the others graduated in length. Commonly the edge of spine toward furrow is broader than that from it. Frequently there are but five large spines (rarely but four), the sixth being much smaller than the rest and placed back slightly from the edge at either end of series. Rarely seven furrow spines are present. (2) On actinal surface are two or three irregular longitudinal series of much smaller and slenderer spinelets which decrease rapidly in size as they recede from furrow. Series adjacent to furrow spines consists of about three or four tapering pointed spinelets, one-half to two-thirds the length of median furrow spines. The outer one or two series are very irregular; sometimes there is no regular serial arrangement at all. The average plate is best shown by the figures.

Mouth plates large and prominent actinally, the combined pair broadest at about the middle. Armature consists of (1) a furrow or marginal series of seven to nine, similar in character to median spines of adambulacral furrow series, which begin at about middle of plate and form a fairly straight series to inner angle, increasing in size as they proceed inward, the inner two or three being broad, flat, and knife-like and in common with the others the edge away from furrow is often thinner than that toward it. (2) Actinal surface is covered with slender spaced spinelets which increase in size toward the suture and inner angle.

Actinal intermediate areas large, the plates being arranged in regular series parallel with furrow, and also in regular series leading from marginal to adambulacral plates. The breadth of ray near extremity is largely due to the intermediate plates, of which four longitudinal series extend 0.39 length of ray (measured from interradial angle); three series, 0.65 or slightly more; two series, 0.7 to 0.8; and the series adjacent to adambulacrals extends about half way between end of latter and tip of ray or about 0.85 total length. In the interbrachial angle there are additional short series; for instance, in a large specimen, a fifth series extends nearly 0.25 length of ray, a sixth to the third or fourth inferomarginal; and counting along interradial line, there are nine or ten plates between the first inferomarginal and third adambulacral (see pl. 13, fig. 2). The plates are strongly carinated, the keel running transversely, each being surmounted by a prominent paxilliform tuft of spinelets, of which the peripheral are very slender and pointed, while the central are usually much stouter, often clavate and three to five sided in section, with flattened flaring tips cut obliquely, which appear to be bent outward toward marginal plates. In such specimens the spinelets of series adjacent to adambulacrals are heavier, often subprismatic also, and square tipped. More often the central spinelets are only slightly heavier than the peripheral; or one or two may be enlarged, and the rest graded in size up to these. Between these actinal paxillæ are deep channels leading from the marginal grooves to the furrows. The plates, from which the carinations spring, are seen to imbricate very strongly when viewed from the cœlomic side, the outer end being often prolonged. Considered from the external surface the latter lies under the inner end of the adjacent plate (in interradial direction).

Madreporic body large (about 9 or 10 mm. in diameter), undulating in outline and hidden by large paxillæ situated on its surface (about eighteen). It is situated a little adcentrally to the middle of the minor radius.

Color in life: Abactinal surface orange yellow, actinal surface lighter yellow.

Anatomical notes.—Superambulacral plates are present as slender rods, slightly flaring at tips, which pass from outer end of ambulacral plates to the first or inner actinal intermediate plates; absent from first two plates, and very small near tip of ray. Gonads, in the form of closely placed dichotomously branched tufts, depend from the genital stolon, extending in a series half the length of ray. Each genital tube consists of two main branches and two or more terminal branchlets. In the specimen examined they pack the cœlom full. These genital stolons are situated on either side of the median radial area slightly less than midway to margin of paxillar area. Anal aperature prominent, with a narrow periproct. It is connected by a short intestine with the large single sack-like intestinal cœcum lying in the left radius of trivium. The lining of the cœcum is traversed by small folds or corrugations. Directly under the anal aperture of cœcum is a slit about 2 mm. long opening into a very short intestine, which leads into the stomach. The latter has much folded walls, and these appear to be no differentiation into dorsal and ventral divisions. Hepatic cœca are large with a spacious interior, which is pinnately divided into simple side pockets with more or less folded walls. A large Polian vesicle in each interradius. Tiedemann organs, two to each interradius, large, and with many fine divisions. Interradial septa single, without calcareous bodies. Stone canal very large. Tube feet large, conical, without calcareous rods in the walls.

Variations.—In medium-sized examples—that is, with R equal to about 70 mm.—the rays are not so broad on the outer part; consequently they seem to taper more evenly. The actinal interradial areas are also smaller, and on outer part of ray there are not so many intermediate plates. The abactinal paxillæ are not so crowded, nor of course so large. Irrespective of size there is a slight variation in marginal plates. The inferomarginals project laterally beyond the superomarginals in a varying amount, and the spines or tubercles are bluntly pointed in some specimens, in others clavate with truncate or concave tips. Some specimens have as many as three superomarginal tubercles, especially on outer part of ray, where they are longer than proximally. The actinal intermediate paxillæ are rather variable, the central spinelets being usually slender (but stouter than the peripheral) and slightly spaced on the keel or tabulum of plate; a very few specimens (two or three) have the central spinelets conspicuously thicker than the peripheral ones, polygonal in section, with truncate tips, these being graduated in size from one or two central spinelets to the peripheral. The spinelets on surface of mouth and adambulacral plates are also variable in arrangement.

The following table will show some of the variations due to size:

Variations in Dipsacaster eximius.

Station.	R.	r.	R : r.	Number of superomarginals.	Second series of actinal intermediate plates.[a]	Third series.[a]	Fourth series.[a]
3112	124	55	2.26 : 1	32-34	0.78+	0.65+	0.39
4334	108	45	2.4 : 1	32	0.8	0.5	0.24
4321	78	31	2.5 : 1	28	0.7	0.41	0.17
2937	30	11	2.7 : 1	24	0.34	0[b]	0[c]

[a] The figures denote how far along ray, measured from interradial angle or first plate, the intermediate plates extend. Thus the second row of actinal intermediate plates in the first specimen extends 0.78 length of ray, the third row 0.65, the fourth 0.39.

[b] To second inferomarginal.

[c] Does not extend beyond first inferomarginal (four plates in all).

Young.—The smallest specimen from station 4333 has R = 13 mm., and is easily recognized as belonging to *eximius*, and as distinct from *D. anoplus* by reason of the spiny inferomarginals extending conspicuously beyond superomarginals, by the wide fasciolar grooves, character of adambulacral and actinal intermediate plates. The abactinal paxillæ are high delicate and more spaced as well as relatively fewer than in the adult. The papulæ are generally distributed as in adult, but not gonads have developed. Adambulacral furrow spinelets four, and only four to six very delicate spinelets to each intermediate plate. The spinulation is open and lacks the compact appearance of *D. anoplus.* (See pl. 16, fig. 3.)

Type.—Cat. No. 22328, U.S.N.M.

Type-locality.—*Albatross* station 4334, Los Coronados Islands, southwest of San Diego, California, 525 to 514 fathoms, green mud.

Distribution.—From north of Monterey Bay (Pigeon Point) to the vicinity of San Diego, California (Los Coronados Islands, Lower California) and from 206 to 525 fathoms, usually on green, black, or yellow mud.

Specimens examined.—A total of twenty-two specimens from the following Californian localities:

Specimens of Dipsacaster eximius examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2896	South of Santa Rosa Island	376	yellow mud	2	U. S. Nat. Mus.
2936	Off Point La Jolla, San Diego	359	mud	5	Do.
2937	Between Santa Catalina and Oceanside	464	green mud	1	Do.
2979	Off Anacapa Island	388	do	1	Do.
3112	Off Pigeon Point, north of Monterey Bay	296	fine gray sand	3	Do.
4321	Off San Diego	206	black mud	2	*Albatross*, 1904.
4333	do	301-487	green mud	1	Do.
4334	Near Los Coronados Islands, southwest of San Diego.	525-514	do	Type.	Do.
4345	do.[a]	[b] 25	gray sand	1	Do.
4123	Between Santa Barbara and San Nicholas Islands.	339-216	shells, black pebbles, green sand.	1	Do.
4427	Off Santa Cruz Island	475-510	black mud, broken stones	4	Do.

[a] Error.

[b] Probably erroneous, or specimen incorrectly labeled.

DIPSACASTER BOREALIS Fisher.

Pl. 12, figs. 1, 2; pl. 13, fig. 1; pl. 14, fig. 2; pl. 52, figs. 2, 2*a*, *b*.

Dipsacaster borealis FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 546.

Diagnosis.[a]—Similar to *D. eximius* in general form, but rays more evenly tapered. Rays broad at base; interbrachial arcs abruptly rounded; abactinal surface nearly plane. R = 117 mm.; r = 51 mm.; R = 2.3 r. Breadth of ray at base, 60 mm. (greater than r). Abactinal paxillæ regularly arranged as in *eximius*, but smaller, and not conspicuously larger along median radial area and center of disk; in latter area they may be even a trifle smaller; spinelets not so numerous as in *eximius* and not extending far down pedicel of paxilla. Papulæ generally distributed, six around each lobed plate; median radial series of plates not conspicuously lobed as in *eximius*, but placed close together; not surrounded by more than six papulæ. Marginal plates massive, the inferomarginals defining contour of ray; superomarginals covered with low granules compactly placed, and on distal portion of ray, bearing one or two inconspicuous tubercles; inferomarginals covered with imbricating scale-like granules becoming more or less flattened tubercles on outer aboral edge; the covering much more compact and resistant than in *eximius;* specialized ridges of inferomarginals thicker, and fasciolar furrows narrower than in that species. Adambulacral plates with four to six long, stout, round-tipped furrow spines, the four largest flattened with side to furrow; on actinal surface about six to nine spinelets in two series, or without regularity. Actinal intermediate areas smaller than in *eximius*, especially on rays; the plates strongly carinated, bearing a compact group of broad scale-like spinelets, surrounded by a row of slenderer curved spinelets.

Description.—By comparing the largest specimen with that of *D. eximius*, the rays, although very broad, are seen to be less arched in contour; that is, they taper more evenly. The paxillæ are decidedly less compact than in *eximius* and more uniform in size across the disk or across the ray. They are arranged in regular oblique transverse rows except along the median radial area and center of disk. But unlike those of *eximius* they are not larger on these areas, being, if different, slightly smaller in center of disk. Thus when the two species are placed side by side the abactinal area has a different facies. It is true that the paxillæ along the median radial area are the largest on ray, but they grade so evenly into the lateral paxillæ that the difference is not so noticeable as in *eximius*. The paxillæ themselves are individually smaller than in *eximius* and the spinelets fewer. These are grouped in a compact bunch at the tip of the shorter pedicel, are seventy to eighty in number on largest paxillæ, and do not extend very far down the pedicel. The median spinelets are blunt, but those on sides are pointed and successively shorter. The spinelets are relatively shorter. Probably a comparison of the figures (pl. 52, figs. 1*a*, 2*a*) of representative paxillæ drawn on the same scale will show the striking difference, as well as the fundamental or "generic" similarity. The paxillæ covering madreporic body are two or three times larger than the others. Opposite first four superomarginals are eleven to thirteen rows of paxillæ.

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[a] From type.

Abactinal plates or bases of paxillæ small, and nearly the same size as in *D. eximius*, those of lateral regular series if anything a trifle larger and more regular. These commonly have five or six very short lobes, which become absolete at tip and toward margin of area where the plate changes from a circular to an elongate contour. The plates of the median radial region are rather more regularly arranged than in *eximius* and are closer together. The carinal or midradial plates are circular with very slight lobes on some of them, and adjacent plates touch them so that the papular areas are small, with single papulæ. (In *eximius* the carinal plates are spaced and strongly lobed with larger papular areas than ordinary.) On the disk, especially toward the center, the plates are much smaller than in *eximius*. They decrease rapidly in size toward the center where they are scarcely larger than the diameter of pedicel or paxilla shaft, circular in outline and widely spaced. Along the course of either large abactinal adradial muscle band the plates form two regular longitudinal rows as shown in figure, and their shape is also slightly altered. Papulæ are distributed all over the abactinal surface, as is characteristic for this genus. They are usually in sixes about each plate, and are never more than one to an area on either side of the mid-radial series of plates, as is the case in *D. eximius* at about the middle of the ray.

The arrangement of the midradial row of plates and adjacent papulæ, as well as the form of plate, and their size toward center of disk, constitute some of the most reliable differences between this species and *eximius*. These are best shown by the figures (pl. 52, figs 1*c*, 2*b*).

Marginal plates massive, the inferomarginals defining the margin of ray when viewed from above. Superomarginals, thirty-four in number from interradial line, are wider than long and form a slightly arched bevel to abactinal surface. They are not quite so strongly arched as those of *D. eximius*, nor are the plates so tumid; and in proportion to length are a trifle wider. The plates are covered with low, flat-topped close-set hexagonal and pentagonal granules, largest near center or upper end, becoming slenderer toward edge of plate, where they assume the form of robust, blunt spinelets, never slender and sharp as in *eximius*. Beyond middle of ray on each plate one to three granules are usually enlarged into short, bluntly pointed tubercles, and are situated on aboral edge of plate, being directed toward edge of ray. On the more distally situated plates the granules increase in size toward this tubercle, which increases in length toward the end of ray but is never conspicuous. The aboral transverse edge of the specialized ridge of plate becomes in this region slightly more abrupt than the adoral edge which is rounded. This is due to the crowding of the large granules toward the aboral edge. The whole covering of the plate is more compact, firm, and graniliform than in *eximius*. The fasciolar grooves between the plates (or specialized ridges of them) are not so broad as in *eximius*, and unlike the latter species, are not evident unless the plate is denuded.

Inferomarginals correspond to superomarginals and encroach conspicuously onto actinal area, about which they form a slightly arched border, the outer ends forming a rounded serrate edge to ray. The specialized ridge of each plate, when denuded, is much thicker than the adjacent furrows, and is relatively thicker and the furrows are relatively much narrower than in *eximius*. The plates are covered with robust squamiform granules, which increase in size toward the aboral edge of plate, the squamules being pointed outward and aborally. On the outer part of the aboral edge (on margin of ray) are a number (six to twelve) of pointed squamiform or tubercular spines directed distad, and forming a fringe overhanging the proximal border of adjacent plate. They are stoutest and bluntest on the very edge of ray and are graduated in size actinally, sometimes extending nearly to inner edge of plate on the distal portion of ray. Frequently they form two irregular series. The squamules of plate are graduated in size up to these. In interbrachial angle where the plates are much shorter the spines form a median row. On the abactinal end of the plate are small granuliform spinelets similar to those on adjacent portion of superomarginal; and on the edge of the fasciolar grooves are slender blunt spinelets. In general, the covering of the inferomarginals is much more compact, heavy, and squamiform than is that of *eximius*. The difference is very striking on comparison of the two forms.

Adambulacral plates about as long as broad, with a rounded furrow margin, and separated by fairly wide sutures. Armature consists of (1) a furrow series of four, five, or six robust round-tipped spines, which are much longer than plate, and are graduated in size toward either end of series. These spines, at least the four central, are usually more or less flattened with the broad side to furrow, and the tip is usually expanded. (The same spines in *eximius* are strongly compressed, tapering, and with edge to furrow.) Commonly, the spine, at either one end of the series or the other, or both, is tapering, much smaller (two-thirds to three-fourths length of large spines), and stands back from the margin, slightly out of line. When there is a smaller spine at both ends of series, there are usually six spines in all. Near extremity of ray there may be but three spinelets in furrow series. (2) On actinal surface of plate are six to nine rather small-spaced, tapering, blunt spinelets, which form two irregular series, or are without definite order. Those nearest margin are longest. The lateral members of the furrow series frequently stand back far enough to be in line with the actinal spinelets. The latter, however, are smaller and distinctly tapered. The first plate is not much modified, and has six or seven furrow spines and a variable number of actinal spinelets. The outer edge of plate abuts against the side of the mouth plate. It is not so compressed as in *eximius*.

Mouth plates prominent, broader at inner than at outer end, with a curved margin at mouth of furrow. Furrow spines in a curved series, eight or nine in number, increasing in size toward the inner end of plate; all are heavy, usually with thick tips, the inner ones being compressed in varying degrees. The spines are not so thin and knife-like as in *eximius*. A series of very small spinelets borders the edge next to first adambulacral, and another, consisting of short but thick and blunt spines, follows the median suture border. These lack regularity in size and shape, but are often quadrate in section, and much thicker than the same spinelets in *eximius*. A few intermediate in position between the two series may be present.

Actinal intermediate areas considerably smaller than in *eximius*, especially on ray. A single series (that next to furrow plates) extends 0.8 length of ray measured along its side; second series, 0.5; third series, 0.23; fourth series, less than

0.18; while a fifth series does not extend beyond the third inferomarginal. (Compare with table under *eximius.*) Between first inferomarginal and third adambulacral are seven plates. The series meeting the first and second adambulacrals do not reach the marginals. Intermediate plates bear a marked tabulum or carination crowned with a very compact group of numerous (about fifteen to twenty) round-tipped, flattened, scale-like spinelets directed toward marginal plates; surrounding this elliptical or ovoid group of imbricating spinelets is a peripheral series of about fifteen to twenty-five slightly curved, round-tipped, slender, flattened spinelets resembling flower petals. Indeed, the whole group greatly resembles an asymmetrical miniature chrysanthemum blossom. The central spinelets are much less numerous in *eximius* and never of the flattened imbricating squamiform shape. The furrows running interradially between the actinal paxillæ are narrower in the present species than in the foregoing.

Madreporic body very large (13 mm. in diameter) with fine centrifugal striations. It is subcircular, with a scalloped edge, and its center is about midway between inner edge of superomarginals and center of disk. The surface is uneven, and is entirely obscured by about thirty to thirty-five very large paxillæ. One of these exceeds the rest in size.

Anatomical notes.—The internal anatomy does not differ in any very important respects from that of *D. eximius:* superambulacral plates the same, as also the details of the water vascular system. The intestinal cœcum is the same shape, but lies in the left bivial interradius (very nearly the position in *eximius*); anus present, of conspicuous size; connections as in *eximius.* Gonads arranged as in *eximius,* but in specimen examined they extend farther along the ray, beyond middle.

Variations.—The variations exhibited by the few available specimens are slight and concern chiefly minor details of ornamentation already mentioned. One specimen from station 3331 has the rays a trifle shorter and broader at the base than the rest. Despite small differences in spine counts, the type facies is maintained by all the specimens, and one can distinguish them at a glance from *eximius.*

Type.—Cat. No. 24341, U.S.N.M.

Type locality.—*Albatross* station 3331, north of Unalaska, 350 fathoms, mud (four specimens).

Distribution.—Bering Sea and south of the Aleutian Islands, 121 to 351 fathoms.

Specimens examined.—Seven specimens, besides four from type locality, one from station 3330, same locality, 351 fathoms, black sand, mud; two from station 3337, south of Unimak Island, 280 fathoms, green mud; one from station 3489, west of Pribilof Islands, Bering Sea, 184 fathoms, green mud; one from station 3500, south of the Pribilof Islands, 121 fathoms, fine gray sand.

Remarks.—As detailed in the foregoing description, this species differs from *Dipsacaster eximius* in the shape of rays in large specimens, in having smaller paxillæ, which have fewer spinelets, and these not descending far down the pedicel; in not having the paxillæ conspicuously enlarged on center of disk and along middle of ray; in the shape and position of median radial plates and in number of papulæ surrounding them; in covering of marginal plates; in having thicker specialized ridges to inferomarginals, with correspondingly narrow fasciolar furrows; in the special spines on both series of marginals; in having differently shaped adambulacral furrow spines; and in having much smaller actinal intermediate areas on rays, as well as a different armature to the intermediate plates. Still other differences have been alluded to in the course of the description.

A fairly well-marked variety, or perhaps representative species, is found in Japanese waters. The principal external differences are the following: The Japanese form has the paxillæ still smaller on middle of disk, a larger madreporic body (possibly not constant), smaller and less compact granules on superomarginal plates; thinner specialized ridges to inferomarginals (more as in *eximius*) with wider fasciolar grooves. The furrow spines are nearly as in *borealis*, but there is frequently an additional spine. Thus the number is usually six or seven, and occasionally eight. The most important difference is in the abactinal plates, so far as my limited examination can determine. In the Japanese form the plates of ray are also lobed, but the median radials or carinals are not so closely placed as in *borealis*. They are also frequently decidedly lobed. The plates along the course of the muscle bands are not modified. The lobing is apparently more distinct in medium-sized than in very large specimens of *Dipsacaster*.

DIPSACASTER LÆTMOPHILUS Fisher.

Pl. 12, fig. 3; pl. 15, figs. 1, 2; pl. 52, figs. 3, 3*a*, 3*b*; pl. 53, fig. 2.

Dipsacaster lætmophilus FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 547.

Diagnosis.—Rays five. R = 118 mm.; r = 45 mm.; R = 2.6 r. Breadth of ray at base 47 to 52 mm. Rays tapering gradually to a bluntly pointed extremity; general form flattened; interbrachial arcs wide; paxillæ regularly arranged as in preceding species, and similar; slightly larger in center of disk than elsewhere. Abactinal plate not lobed, except rarely on median radial area; papulæ generally distributed, in sixes about each plate. Marginal plates massive; superomarginals nearly quadrate beyond proximal fourth of ray, covered with close-set delicate spinelets like those of paxillæ and without specialized spines or tubercles; inferomarginals narrower than in preceding two species, covered with delicate imbricating narrow squamiform spinelets which become enlarged into five to seven small tapering spines on outer aboral end of plate, causing a decidedly serrate appearance to edge of ray; fasciolar furrows rather wide. Adambulacral furrow spines seven very strongly compressed and blade like, their edges to furrow; tip much broader than base, rounded and thin like a knife; on actinal surface ten to eighteen slender tapering or clavate spinelets, decreasing in size outward. Actinal intermediate plates extending far along ray; intermediate areas about as extensive as in *borealis*, but a single row of plates extending 0.9 length of ray measured from interradial angle.

Description.—Rays are narrower than in either of the two preceding species, but broader than in *D. nesiotes* Fisher. Paxillæ regularly arranged along sides of area, slightly larger in middle of disk than elsewhere (except on madreporic plate); along mid-radial area not markedly larger than along either side contiguous to this area. Paxillæ very similar to those of *D. borealis*, the numerous spinelets (eighty to over one hundred on large paxillæ) slender and blunt, the most centrally situated ones forming a flat-topped group, those about periphery forming one or two irregular tiers graduated in length (see pl. 52, fig. 3*b*). Ten or eleven transverse rows of paxillæ correspond to first four superomarginals.

Unlike the two preceding species, the abactinal plates are not lobed, except occasionally very slightly on mid-radial areas. (In *D. nesiotes* the abactinal plates are circular, but placed more closely than in the present form.) Plates of the regular lateral paxillar rows are subcircular, but the slight flange above the true base of the plate or paxilla is frequently rather irregular. On the radial areas the plates are more widely spaced, uneven in contour, with slight traces of lobes sometimes, and without regularity in arrangement. Papulæ distributed all over paxillar area; in sixes about plates, but occasionally on the irregular median radial area there are seven or eight.

Marginal plates typical of genus; inferomarginals defining contour of ray, forming a serrate edge. Superomarginals, thirty-five in number from interradial line, are nearly quadrate except in interradial angle, where they are much wider than long. General surface is covered with slender and delicate, pointed spinelets about the size of those on paxillæ, forming a close nap very unlike either *D. borealis* or *D. eximius*, but similar to *D. nesiotes*. No specialized tubercles on superomarginals.

Inferomarginals correspond to superomarginals, and do not encroach onto actinal surface so much as in *D. borealis*. Surface is covered with delicate, imbricating, narrow squamiform spinelets, which increase in size toward the outer aboral edge of plate, there forming a tuft of five to seven small tapering spines, as in *D. nesiotes*. The abactinal end of plates is covered with slender spinelets like those of superomarginals. The fasciolar furrows are wide and lined with delicate terete spinelets. In proportion to length, the plates are much narrower (and are actually so) than in *eximius* or *borealis*, but are shorter and wider than in *nesiotes*. Compared with the latter species, the fasciolar grooves are much wider and the specialized ridge not so thick.

Adambulacral plates with a furrow series of seven very strongly compressed bladelike spines, their edges to furrow, and graduated toward either end of series. These spines are much broader and thinner at tip than at base, the edge at tip being rounded, laminar, and knifelike. On actinal surface are about ten to eighteen slender, tapering or clavate spinelets decreasing in size outward. Those nearest furrow are subequal and largest, and commonly form a longitudinal series of five to eight.

Mouth plates elongate, the combined pair very tumid and the whole surface bristling with spaced spinelets similar to those on actinal surface of adambulacrals. Free margin with seven to nine compressed spines like those of adambulacrals, these increasing in size toward the inner end of plate.

Actinal interradial areas fairly large, the intermediate plates about as numerous, and intermediate areas as extensive on rays, as in *borealis*. The series adjacent to adambulacrals extends 0.9 length of ray; the second, 0.6 to 0.65; the third, 0.3; the fourth, 0.15; a fifth extends to fourth inferomarginal; between third adambulacral and first inferomarginal is an interradial series of nine plates, the additional plates being added rapidly between first and fourth inferomarginal. The first row extends very slightly farther along ray than in either of the two preceding forms. Actinal plates bear a low carination (of narrow elliptical form) crowned with small papilliform spinelets, those in center being clavately thickened and fifteen to thirty in number, the peripheral, about twenty or less according to size of plate, being slenderer.

Madreporic body about midway between extreme margin and center of disk, 11 mm. in diameter, and hidden by about twenty-five large paxillæ.

Anal aperture of conspicuous size, though hidden by paxillæ; tube feet large, pointed, without calcareous grains or rods in walls.

Type.—Cat. No. 24672, U.S.N.M.

Type-locality.—*Albatross* station 3340, south of Alaska Peninsula, between Unalaska and Kadiak (lat. 55° 26′ N.; long. 155° 26′ W.), 695 fathoms, mud; one specimen.

Distribution.—Known only from the type-locality.

Remarks.—This species differs from both of the foregoing forms in the following characters: Form of abactinal plates; width, covering, and special armature of marginals; armature of adambulacrals. From *D. eximius* it further differs in the size and character of abactinal paxillæ; shape of rays; in distribution of papulæ along mid-radial line; in having narrower superomarginals; form of outer end of inferomarginals due to different armature; in having narrower actinal intermediate areas on rays; and a different armature, as well as less prominent carinations to actinal intermediate plates. From *D. borealis* the present species further differs in having slightly narrower rays (probably not constant); larger paxillæ in center of disk; in armature of actinal intermediate plates which have less prominent carinations; in armature of mouth plates. *D. lætmophilus* differs from *nesiotes*, of the Hawaiian Islands, in having much broader rays; longer paxillæ pedicels in proportion to width of crown of spinelets; more distantly spaced abactinal plates; marginals which correspond plate for plate and do not alternate on outer part of ray; wider superomarginals and inferomarginals, especially the latter; a less plane actinal surface to inferomarginals; less thick specialized ridge; broader fasciolar grooves; more prominently carinated actinal intermediate plates; larger actinal intermediate areas on rays. The armature of adambulacrals and mouth plates is very similar in the two forms, as well as the finer spinulation of marginals and absence of special superomarginal spines or tubercles.

DIPSACASTER ANOPLUS Fisher.

Pl. 16, figs. 1, 2; pl. 52, figs. 4, 4*a*.

Dipsacaster anoplus FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 547.

Diagnosis.—Rays five. R = 25 mm.; r = 12.5 mm.; R = 2 r. Breadth of ray at base, 13 mm. General appearance greatly resembling a species of *Leptychaster*[a] (as *L. pacificus* or *L. anomalus*). Rays tapering more or less gradually to a bluntly pointed extremity; sometimes slightly swollen on outer part; interbrachial angles wide. Abactinal paxillar area fairly compact; paxillæ arranged in oblique rows at sides of median radial area; pedicels high, pestle-shaped, with a crown of thirty to forty spinelets, of which about one-half form a peripheral series; abactinal plates feebly lobed, or round and crowded at center of disk; papulæ absent from center of disk and in young specimens also along median radial area; papulæ in fives and sixes about each plate. Marginal plates entirely without enlarged spines or tubercles, and with deep and wide fasciolar grooves and narrow specialized ridges; inferomarginals usually not extending beyond superomarginals. Adambulacral plates about as long as broad, with a furrow series of five or six subcylindrical bluntly pointed spinelets, and on actinal surface twelve to eighteen spinelets decreasing in size outward; those adjacent to furrow series form an irregular series of five or six, the rest without definite order as a rule. Actinal interradial areas extensive; actinal intermediate plates extending two-thirds the length of ray, strongly carinated and bearing a paxilliform group of rather long, slender spinelets. Madreporic body hidden; not so large as in other species of genus. Gonads extending far along ray in sexually mature forms. Anal aperture present, opening out from an undivided sac-like intestinal cœcum.

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[a] See *Remarks* on p. 100.

Description.—Abactinal paxillar area fairly compact; paxillæ arranged in oblique transverse rows at either side of median radial line, decreasing abruptly in size from inner third of minor radius toward center of disk and gradually toward extremity of ray. Each paxilla consists of a slightly lobed or roundish base, immersed in the dorsal integument, from which arises a comparatively high round-tipped pedicel, broader at extremity than at base, crowned with a divaricate group of slender spinelets. A large paxilla has about fifteen to twenty spinelets in the peripheral series and an equal number forming a group in the middle. The spinelets are about half as long as the pedicel. Small specimens have fewer spinelets.

Abactinal plates (or base of paxillæ) feebly lobed, or in youngest examples round. In the type there are five or six very short lobes, but in small examples the plates are indefinite in outline. In center of disk they are always round and crowded. Papulæ absent from center of disk, and along median radial area are either absent or interrupted in distribution in small examples; but in type the papulæ extend all the way across ray; papulæ in fives and sixes about each plate.

Marginal plates without specialized spines of any sort, thus resembling *Leptychaster*, and with wide, deep fasciolar channels between the raised ridges. Superomarginals, seventeen in number from interradial line, do not encroach much onto abactinal surface, but are confined largely to side wall of ray. Each plate is wider than long, and the raised ridges when denuded are less in thickness (or width, counting the lesser dimension) than the intervening channels; sometimes a ridge is only one-half as wide as the furrow. Each plate is covered with short, slender, and blunt papilliform spinelets, becoming slenderer and longer in the fasciolar grooves. Terminal plate, considerably broader than long, concave toward paxillar area, and with two thimble-shaped spines on either side of the terminal papilla.

Inferomarginals extending but a trifle if at all beyond the superomarginals in largest specimens; in small examples, usually somewhat, toward end of ray. The plates encroach conspicuously onto actinal area, to which they form a strongly arched margin; and viewed from the side they occupy considerably more than half of side wall of ray. The plates are covered with spinelets similar to those of superomarginals, only thicker.

Adambulacral plates about as long as broad, not compressed, with a rounded furrow margin and wide sutures between the plates. Furrow spinelets, five or six, usually five, subcylindrical, bluntly pointed, the lateral slightly the shortest, the median about as long as plate. On actinal surface of plate are twelve to eighteen spinelets, those adjacent to furrow spinelets largest and forming an irregular series of five or six. The others sometimes suggest two irregular series, but are usually without order. The first plate is shorter than the rest.

Mouth plate very prominent actinally, the free margin occupying about one-half the length; median suture, narrow elliptical, the outer end of plates diverging slightly from interradial line. Marginal spinelets eight to ten, slender and pointed, the innermost abruptly larger than remainder. A series of slender blunt spinelets follows the margin of median suture, and parallel with it an intermediate series, while along the margin adjacent to first adambulacral are several very slender, smaller spinelets, with two or three odd spinelets out of line on surface of plate.

Actinal interradial areas extensive. The actinal intermediate plates are strongly and narrowly carinated, and a single series extends two-thirds length of ray measured from interradius, a second series about one-third, a third series to the third inferomarginal, and between first inferomarginal and second adambulacral are four intermediate plates in an interradial series. The intermediate plates bear a paxilliform group of rather long slender spaced spinelets, the peripherally placed ones being directed over the deep fasciolar channels between the raised tabula of plates.

Madreporic body slightly nearer margin than center of disk. It is smaller than in typical *Dipsacaster* and is entirely obscured by paxillæ, one or two of which arise from its surface. The striations are fine and radiating.

Anatomical notes.—Superambulacral plates present, except on first ambulacral plate, and on the distalmost. Gonads extending far along ray, the genital tubes largest in interradial regions, thence decreasing in size distad. The arrangement appears to be as in typical *Dipsacaster* except that the genital stolon is nearer marginal plates. Immature specimens may be found in which the gonads are still confined to the interradial region. Anal aperture present, and easily seen. It connects directly with an unbranched sac-like intestinal cœcum, lying in the left radius of the trivium. Its inner surface is rugose. The opening into the very short intestine is slit-like, and is situated just below the anal aperture, on a low prominence. A single Polian vesicle in each interradius. Tube feet pointed, without sucking disks, and without deposits in walls.

Variations.—In some specimens the rays are broader and shorter than in others, and in these the inferomarginals extend laterally beyond the superomarginals; while there is also variation in the form of the tip of the ray, this being more rounded in a few examples than in the type. These small differences cause a considerable difference in the general facies of the species. Unfortunately most of the specimens are undoubtedly young, on account of the condition of the gonads. The variation in the distribution of the genital tubules is due to age, the gonads appearing first in the interradial region and thence progressing along the ray. Fully developed gonads are found in individuals with R = 13 mm., but some examples equally large have undeveloped gonads. In such an event one relies upon the general facies, structure of marginals, characteristic terminal plate, and the tall slender paxillæ, as well as the characteristic furrow armature to determine the species.

Type.—Cat. No. 24675, U.S.N.M.

Type-locality.—*Albatross* station 3347, off Cascade Head, Oregon, 345 fathoms, mud (2).

Distribution.—Washington to vicinity of San Diego, California, and between 300 and 800 fathoms, usually on mud.

Specimens examined.—Forty-five specimens, including type, from the following stations:

Specimens of Dipsacaster anoplus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2839	Between Santa Catalina and San Clemente Islands, California.	414	gray sand	26	U. S. Nat. Mus.
2925	Off San Diego, California	339	mud	1	Do.
2937	....do	313	green mud	2	Do.
2980	South of Santa Cruz Island, California	603	....do	2	Do.
3075	Off Sea Lion Rock, Washington	859	....do	1	Do.
3347	Off Cascade Head, Oregon	345	mud	2	Do.
4347	Off San Diego, California	161–510	fine gray sand, green mud.	1	*Albatross*, 1904.
4351	....do	423–488	green mud	1	Do.
4380	Near Los Coronados Islands, Lower California.	530–638	gray sand, green mud	2	Do.
4405	Between San Clemente and Santa Catalina Islands, California.	654–704	green mud	1	Do.
4407	....do	334–600	rocks, shells, fine gray sand	1	Do.
4415	Between Santa Catalina and Santa Barbara Islands, California.	638–302	green mud	1	Do.
4416	Between Santa Barbara and San Nicholas Islands, California.	448–323	dark green mud	2	Do.
4427	Off Santa Cruz Island, California	475–510	green mud	2	Do.

Remarks.—This species bears a striking resemblance to *Leptychaster* (for instance a form about intermediate in external appearance between *L. anomalus* and *L. pacificus*) principally on account of the unarmed marginals and the general facies of the actinal surface. The structure of the gonads, character of paxillæ as well as the distribution of papulæ and presence of a conspicuous anal aperture remove the species from that genus. At the same time it must be admitted that its relegation to *Dipsacaster* is open to criticism. The marginal plates, especially the inferomarginals are unlike those of *Dipsacaster*, and the absence of papulæ from the center of disk is an important difference. The madreporic plate is relatively smaller than in typical *Dipsacaster*, and although hidden, only one or two paxillæ arise from its surface, instead of many. The general form of the paxillæ, form of intestinal cœcum, well developed anal aperture, and distribution of gonads have been the characters which have led me to place the species in *Dipsacaster*. The distribution of gonads would prevent the species being ranked under either *Patagiaster* Fisher or *Leptychaster* Smith (including *Parastropecten*). Ludwig's genus is founded upon evidently immature specimens.

The present species undoubtedly brings *Dipsacaster* much closer to *Leptychaster*, and it may be regarded as an extremely aberrant member of the former.

Genus DYTASTER Sladen.

Dytaster SLADEN, Narr. *Challenger* Exp., vol. 1, 1885, p. 608; *Challenger* Asteroidea, 1889, p. 60. Type,[a] *D. nobilis* Sladen.

Crenaster[b] PERRIER (not d'Orbigny), Annales des sci. nat., 1885, p. 71; Expéd. sci. du *Travailleur* et du *Talisman*, 1894, p. 306.

Diagnosis.—Disk rather small; rays very long and attenuate often subcarinate along the median line abactinally, very slightly flexible. Marginal plates rectangular; the superomarginals thin and lamelliform, confined more or less to the lateral wall of the ray, which is usually vertical. Plates of upper series directly superposed on the corresponding plate of the inferior series, and the contingent horizontal margins of both plates are consequently straight. Plates of both series usually armed with one more or less prominent thorn-like spine, but this may be aborted or may be absent, especially in young forms. The general surface of the plates of both series covered with short papilliform spinelets or granules. Abactinal area with small rounded scale-like plates bearing small paxillæ more or less well developed; no definite order of arrangement. Papulæ numerous or not, generally distributed (?) or absent from outer half of ray. Actinal interradial areas fairly well developed, with numerous intermediate plates arranged in more or less definite columns. Armature of adambulacral plates consisting of a longitudinal furrow series of short spines standing parallel to one another and one or more longitudinal series of papilliform spinelets or granules on the actinal surface; in some forms the first series are well-developed spinelets and nearly as large as those of furrow series; and in some there is a single enlarged spinelet among the first series. Madreporic body very large, compound, placed near the marginal plates and covered with numerous paxillæ. Pedicellariæ (subvalvular) may be present on the abactinal and actinal interradial areas. Anus present, subcentral. Actinostome and ambulacral furrows wide; tube feet pointed. Gonads (always?) extending, in numerous dichotomously branched tufts, far along ray in a series parallel with marginal plates.

DYTASTER GILBERTI Fisher.

Pl. 17, figs. 1–3; pl. 53, figs. 3, 3*a*.

Dytaster gilberti FISHER, Bull. Bur. Fisheries for 1904, vol. 24, p. 300, June 10, 1905.

Diagnosis.—Related to *D. exilis* Sladen. Rays five. R = 114 mm.; r = 22 mm.; R = 5.2 r. Breadth of ray at base 22 mm.; at tenth superomarginal, one-fourth length of ray, 17.5 mm. Rays elongate, robust, tapering at first very slightly, then more rapidly, to a pointed, attenuate, extremity; abactinal integument inflated on disk, plane on rays; lateral wall of ray vertical on proximal half, gradually arching inward and upward on outer half, so that marginal plates form a steep bevel; interbrachial arcs rounded. Ambulacral furrows wide; tube feet large and pointed. Paxillæ small, without regular order, with fifteen to twenty short papilliform spinelets on larger ones; certain scattered paxillæ with two, three, or four jawed pedicellariæ; papulæ absent from terminal 0.4 of ray. Superomarginal plates fifty, subquadrate, slightly tumid, bearing a single tapering spine on upper edge, forming a longitudinal series along dorso-lateral margin of ray except very end; a similar spine on middle of each inferomarginal, forming a similar series on ventro-lateral border; marginals covered with fine nap-like spinulation, increasing in size toward middle of plates, and lower edge of inferomarginals. Adambulacrals long and narrow with ten short furrow spinelets, and about two rows of much shorter ones on actinal surface; distal most plates with an enlarged central spine. Actinal interradial areas small, the plates extending to sixth or seventh inferomarginal and covered with spaced spinelets. A few pedicellariæ consisting of three or four clavate, curved, often scoop-shaped jaws, evidently modified spinelets, to each interradial area. Madreporic body very large, hidden by about forty large paxillæ. Superambulacral plates present; gonads extending far along ray.

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[a] No type was mentioned by Sladen in his original description of the genus in the Narrative, but he fortunately mentions that "at the same station (No. 325) was dredged the genus *Dytaster*." The only *Dytaster* taken at that station was *D. nobilis*, upon which he evidently based the generic diagnosis. The genus should date from 1889.

[b] This name has no status in nomenclature, irrespective of the status of the group to which it has been applied. *Crenaster* has been employed previously in zoology by d'Orbigny. (Prodrome de paléontologie, vol. 1, 1850, p. 340.)

Description.—Abactinal paxillar area nearly flat on ray, slightly convex on disk, and on outer third of area becoming rapidly very narrow, so that for a considerable distance near the extremity only three or four longitudinal rows of small paxillæ separate the superomarginal plates of either side. Paxillæ rather small, without definite order, and rather crowded on disk but distinctly spaced on ray; at base of ray, about four paxillæ opposite each superomarginal. Each paxilla with a pedicel broader at tip than at base, the former being often elliptical when viewed from above; paxilla crown consisting of a nearly flat topped, subcircular or four-cornered group of short, cylindrical, papilliform, obtuse, equal-sized spinelets, or the peripheral slightly slenderer. There are fifteen to twenty spinelets to a paxilla at base of rays, even more on disk, and about twelve to fifteen at outer part of ray. These stand vertically, the peripheral series flaring a trifle on disk and basal portion of rays, but on outer part of ray the peripheral series radiate widely. The paxillæ are a trifle smaller along midradial line than on either side, and are largest on interradial areas of disk and adjacent portions of the rays. Scattered rather widely over disk and rays, but occurring especially adjacent to superomarginals, certain paxillæ bear a single two, three, or four jawed pedicellaria. The jaws are very much stouter than the spinelets, but do not extend much above their general level, and are curved toward each other, being scoop-shaped at the tips. These pedicellariæ are very inconspicuous. Sometimes they replace all the spinelets of a pedicel, but usually there is a more or less interrupted peripheral series surrounding them like the calyx of a flower.

Abactinal plates crowded, often slightly overlapping, subcircular, irregular, or with slight indication of lobing, especially on disk. Papulæ small, rather irregular in position, absent from distal 0.4 of ray, and on disk from numerous narrow areas radiating from center. There are usually about four papulæ around the paxillæ; occasionally five, often only three.

Marginal plates thin. Superomarginals, fifty in number from median interradial line to extremity of ray, nearly quadrate except in interbrachial arc, where they are higher than long; plates confined to side wall, except that the upper end (representing the thickness of plate) forms a very narrow border to the paxillar area. At the base of the ray the plates are vertically oriented, but beyond the basal 0.4 they slope upward and mesially (together with the inferomarginals), thus forming a steep bevel. At the end of ray the inferomarginal plates with their spines define the contour of ray. Each plate is slightly tumid and bears a rigid, erect, robust, tapering spine, at about the middle of the abactinal end, and approximately as long as the height of plate. These spines decrease in size distad, and are apparently lacking on the last few plates. General surface of plates covered with very small papilliform spinelets, which are spaced and slenderer at edges of plate than in center. No fasciolar channels. Terminal plate longer than wide, notched toward paxillar area, and apparently covered with fine spinelets, although these are rubbed off.

The inferomarginals correspond plate for plate with superomarginals (except at extreme tip of ray, where there is one additional plate) and the slight tumidity of the latter merges into that of the former without a break at intermarginal suture, and the spinelets are also the same, but increase in size toward inner and lower edge of plate, being more widely spaced on the actinal surface. The plates encroach slightly onto actinal surface, forming an abruptly rounded border, about as much of a plate belonging to lateral as actinal surface. In center of each stands a tapering rigid spine, forming a series all along ventro-lateral margin, and extending outward at right angles. These are a trifle longer than corresponding superomarginal spine. On first two inferomarginals (by a slip of the pen, erroneously stated superomarginal in original description) is an additional spine between the regular spine and actinal margin of plate. The superomarginal and inferomarginal series of spines are very regular.

Adambulacral plates much longer than wide, with a slightly curved furrow margin. Armature consists of (1) a furrow series of ten (eight or nine sometimes) fragile, slightly tapering, round-tipped, faintly compressed spinelets, which are slightly bent at the base and graduated toward either end of the series. (2) On the actinal surface just behind the furrow series is a longitudinal row of about nine much shorter, thick, clavate spinelets, and on the outer edge of the plate is a series of delicate, slender tapering, papilliform spinelets which follow the contour of the plate and are smaller than the other series. On the outer part of ray the plates become very narrow, and although the spinelets are mostly rubbed off, two or three plates near the tip still retain an enlarged actinal spine. Only the distal most plates seem to have this.

Mouth plates large, prominent actinally, and the united pair broadest at middle, but only slightly narrower at outer end; lateral margins toward furrow slightly excavated, and the end toward actinostome truncate. (Unfortunately the armature in the specimens examined has been largely rubbed off.) Marginal series much like that of adambulacral plates, and consisting of about fourteen spines, compressed and curiously expanded above the slender base, from this expansion tapering to the extremity. These spines seem to increase in size toward the inner angle, where there are six larger and heavier teeth. General surface of plates covered with small papilliform spinelets similar to those of actinal intermediate plates, and increasing in thickness at inner angle.

Actinal intermediate areas small, the intermediate plates, which are slightly convex, extending to sixth or seventh inferomarginal, those adjacent to the adambulacral plates being largest. The plates are armed with spaced, radiating, small, papilliform spinelets. In a smaller specimen than the type several plates of each area bear a peculiar pedicellarian apparatus consisting of three or four shorter, thickened, clavate spinelets. These jaws are curved toward each other, and the tip is usually broadened and scoop-shaped. The type has only one or two to each area.

Madreporic body large, 8 mm. in diameter, situated a little more than half its own diameter distant from the margin, and hidden by about forty large ornate paxillæ, which stand flush with the general surface. These paxillæ are larger than any on the general abactinal surface and their spinelets are heavier and more clavate, those situated on the periphery being slenderer, however, and apparently sharp or even mucronate.

Anatomical notes.—Superambulacral ossicles present, though very small; absent from first ambulacral, and beyond middle of ray, or else rudimentary. Gonads in very numerous small tufts, these distributed in a linear series parallel to marginal plates, and extending beyond middle of ray (for about two-thirds length in type). Upper and lower ends of ambulacral ossicles very broad, the lower end with a median keel. Tube feet large conical pointed, without deposits. Anus present.

Type.—Cat. No. 22331, U.S.N.M.

Type-locality.—*Albatross* station 4397, off San Diego, California, 2,196 to 2,228 fathoms, gray mud; two specimens (all that have been examined).

Remarks.—Among the species dredged by the *Challenger*, *D. gilberti* appears to be nearest *D. exilis*, but differs from that form in having shorter and broader rays, the sides of which are high, and arched inward toward the dorsal surface distally, in having less crowded paxillæ with a greater number of spinelets, more numerous marginal plates, the ventral series of which do not encroach upon the actinal area to any great extent; a rather less numerous series of furrow spinelets; in having abactinal pedicellariæ. There is no carination of the rays as in *D. exilis carinata*. The inward arching of the sides of ray mentioned above is not so pronounced in a smaller mutilated specimen from the same station. The shape of the ray is, however, characteristic. The sides are straight or a trifle swollen above the base and do not have the arcuate taper of *grandis* (=*madreporifer* Sladen, 1889, pl. 3). The paxillar area is broader at base and narrower at extremity than in *spinosus*, and therefore much wider than in *exilis*.

Allowing for variation *D. demonstrans* Ludwig [a] appears to be very close to the present species. The marginal plates and proportions are practically the same, but the paxillar area does not appear to narrow so abruptly distad, nor to be so wide at base of ray, judging by figure. The paxillæ are slightly larger in *gilberti* and the papulæ probably not so numerous, there being rarely six about the plates, this being the rule in *demonstrans*. There are a few other minor differences. Whether *demonstrans* can be retained after a series of *gilberti* is dredged remains to be seen. I think it probable that the former will be found to be identical with the latter, although at present the two forms appear doubtfully distinct.

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[a] Mem. Mus. Comp. Zoöl., vol. 32, 1905 (July 17), p. 41, pl. 5, figs. 23–25; pl. 18, figs. 97–99; pl. 19, fig. 107; pl. 20, figs. 108–115.

Family LUIDIIDÆ Verrill, 1899.

Luidiinæ SLADEN, *Challenger* Asteroidea, 1889, pp. 175, 244.

Luidiidæ VERRILL, Trans. Conn. Acad., 1899, p. 201.—FISHER, U. S. Fish Comm. Bull., 1903, pt. 3, 1906, p. 1031.

Astropectinidæ (part) GRAY, 1840, and succeeding authors to Verrill.

Phanerozonia near the Astropectinidæ, but without anus, intestine, or intestinal cœca; superomarginals aborted, represented by paxillæ; inferomarginals, adambulacrals, and actinal intermediate plates forming regular transverse series, the first two being correspondent in number; papulæ compound, the extremity forming a tuft of papillæ.

Remarks.—Sladen places the *Platasterias*[a] of Gray in this group. There are several morphological features of importance concerning which we have no information. Gray's description directly contradicts Sladen's statement, but the former, judging by figures, is evidently inaccurate and misleading. He says, for instance, that there are no marginal plates. The correspondence in position of actinal, adambulacral and inferomarginal plates is the only feature which *Platasteries* has in common (according to descriptions) with *Luidia*. But the absence of an intestine and cœcum, and the character of the papulæ are more important, I think. Sladen states that *Platasterias* has superomarginals, so that the genus may really belong in the Astropectinidæ near *Ctenophoraster*. Until definite information is forthcoming it may remain provisionally a member of this family, although I think that it will ultimately be placed in the Astropectinidæ. The presence of superomarginals certainly would exclude the genus from the Luidiidæ. If, however, *Platasterias* lacks an intestine and cœcum, and has papulæ similar to those of *Luidia*, then the feature of the superomarginal plate would be outweighed, and should be dropped from the family diagnosis. At present, however, there is no evidence upon which to base a conclusion.

Genus LUIDIA Forbes.

Luidia FORBES, Mem. Wernerian Soc., vol. 8, 1839, p. 123. Type *L. fragilissima* Forbes=*L. ciliaris* (Philippi).

Hemicnemis MÜLLER and TROSCHEL, Monatsber. Akad. Wiss. Berlin, April, 1840, p. 105. Type, *L. ciliaris* (Philippi)).

Petalaster GRAY, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 183. Type, *P. hardwickii* Gray.

Diagnosis.—Rays five or more, long, usually narrow, and depressed; disk small; abactinal surface covered with true paxillæ, frequently in regular longitudinal rows at sides; superomarginal plates paxilliform, similar to adjacent paxillæ but frequently larger; inferomarginals with a transverse series of spines or spinelets; fasciolar channels deep and wide; actinal interradial area very small; actinal intermediate plates extending nearly to tip of ray in a single series (exceptionally two or three series are present, and plates rarely absent), the inferomarginals, intermediate plates and adambulacrals corresponding in a transverse series. Papulæ compound, i. e., with distal portion subdivided into numerous papillæ. Pedicellariæ frequently present, sessile, two or three jawed as a rule, either conical, tong-shaped or low and bivalved. Tube-feet in two rows, without true sucking disks. Superambulacral plates present, well developed. Anus and intestinal cæcum absent. Gonad in numerous tufts forming a linear series, all along either side of abactinal integument.

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[a] Proc. Zool. Soc., 1871, p. 136, pl. 9 (Tehuantepec, Mexico).

KEY TO THE SPECIES OF LUIDIA HEREIN DESCRIBED.

a^1. Lateral abactinal paxillæ with a quadrate or subquadrate tabulum.
  b^1. No pedicellariæ; abactinal surface drab gray or greenish gray in life .... *foliolata*, p. 106.
  b^2. Pedicellariæ (bivalved) on inferomarginal plates (abactinal end) and on superomarginal paxillæ, and trivalved upright pedicellariæ on actinal intermediate plates; abactinal surface reddish in life, sometimes mottled with lighter .... *ludwigi*, p. 113.
a^2. Paxillæ with stellate crown; granuliform abactinal two-jawed pedicellariæ; slender two-jawed actinal intermediate pedicellariæ; rather prominent lateral spines .... *asthenosoma*, p. 116.

LUIDIA FOLIOLATA Grube.

Pl. 19, figs. 1–3; pl. 21, figs. 3–5; pl. 54, fig. 3.

Luidia foliolata GRUBE, 43. Jahresber. d. schles. Ges. vaterl. Cultur, Breslau, 1866, p. 69 (no locality).—LUDWIG, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 80.—FISHER, Proc. Wash. Acad. Sci., vol. 8, 1906, p. 121.
Luidia foliata SLADEN, *Challenger* Asteroidea, 1889, pp. 247, 742.

Diagnosis.—From a large specimen, station 4457. R=222 mm.; r=28 mm.; R=8.64r. Breadth of ray at base, 32 mm. Rays five, long, evenly tapered to a sharp but not attenuate extremity; abactinal surface of rays compact, well arched but subplane along median area; interbrachial angles acute; rays constricted at base. No pedicellariæ. Abactinal paxillæ quadrate along either side of ray forming four regular series; much smaller and irregular on median portion of ray. Abactinal plates cruciform. Inferomarginals broad with a transverse row of three flattened lanceolate pointed or blunt spines on outer half of plate; other spinelets slender, not squamiform and chaffy. Adambulacral plates well spaced; armature as follows: One saber-shaped furrow spine and on actinal surface three to five slender, slightly tapering, bluntly pointed spines, accompanied by a variable number of much smaller spinelets. Actinal intermediate plates in a single longitudinal series on ray, each bearing a tuft of spinelets but no pedicellariæ. Mouth plates with a compact group of numerous small spinelets on face toward actinostome, and numerous spines on exposed surface. Color, olive drab or pinkish gray, usually the former.

Description.—Abactinal paxillæ quadrate along either side of ray, forming four regular series and decreasing in size toward median area of ray where the paxillæ are small, irregular, and not arranged in series. Superomarginal paxillæ largest, closely appressed to upper end of inferomarginal plates, bearing on tabulum twenty to thirty polygonal, flat-topped granules decreasing in size toward periphery, which is surrounded by about forty slender and, unless seen from side, inconspicuous spinelets, the whole having the exposed surface very flat. The other paxillæ resemble these, but differ in size as indicated above.

When the abactinal body wall is treated with caustic potash and viewed from the inner side the plates or bases of paxillæ are seen to be very strongly cruciform; that is, with four lobes. By these processes or arms, which are fairly stout, untapered, truncate, or notched at tip, the plates overlap regularly along the four lateral rows of paxillæ, irregularly over median area of disk, where the plates may have three or five lobes each. On the lateral plates the transverse axis is raised into a keel, which, as the plates are in regular transverse rows, forms a transverse ridge about the width of four paxillæ, the lobes overlapping strongly. This keel is absent from superomarginal plates, which have rather wider lobes than the adjacent series, that lobe impinging on the inferomarginals being shorter and rounded. Inferomarginals lobed also, but those on the longitudinal axis (of ray) very short. Plates on central portion of ray and on center of disk very small in comparison to regular lateral ones. Everywhere on the abactinal surface, in the relatively large spaces between the plates, emerge the papulæ, four about each plate. These papulæ are compound; that is, the summit is broad and subdivided into many papillose subdivisions, forming a flat-topped group resembling a decalcified low paxilla.

Inferomarginal plates separated, as usual, by deep fasciolar grooves lined by densely placed capillary spinelets on the outer but not on the inner part. Exposed surface armed with a transverse row of three robust, short, flattened, lanceolate, blunt, or pointed spines on the outer half of the plate, these forming three longitudinal series all along edge of ray; median spine usually longest (4 mm.) equaling about one-half width of actinal surface of its plate; occasionally innermost longest; outermost spine of series decreasing more rapidly than median as series proceeds along ray, so that at outer part of ray these are reduced to small spinelets; median and inner spines frequently become broader in proportion to length on outer part of ray, where they very gradually decrease in length. On first dozen plates there are usually four or five spines in each transverse row. Remainder of actinal surface beset with diverse sizes of flattened, blunt, or truncate, rarely pointed, spinelets; two or three in median line larger than rest, more flattened, broader, and usually very blunt or truncate, forming continuation of series of marginal spines. Spinelets become more slender toward edge of exposed surface, grading very abruptly into capillary spinelets lining grooves. These actinal inferomarginal spinelets are much longer and larger than the flattened chaffy squamiform granules of *L. brevispina* Lütken. Abactinal end of plate with a number of flat-topped granuliform spinelets intergrading on the one side with spinelets of actinal surface and on the other with those of superomarginal paxillæ. Usually just external to outermost marginal spine is a small flattened, sharp, lanceolate spinelet, the series of which dies out before the middle of the ray is reached. Terminal plate strongly concave toward paxillar area, crescent-shaped from above, and covered with granules enlarged distally.

Adambulacral armature consisting of a saber-shaped furrow spine, and on actinal surface three to five slender slightly tapering, bluntly pointed spines, accompanied by a variable number of much smaller spinelets. Of these the innermost spine stands in line with furrow spine and is longer than latter. At base of ray the remaining four or five usually form two transverse series, being accompanied by a number of delicate spinelets on the edge of the plate, or farther along ray one, and finally both of the outer series disappear, and either one of the first series, even, becomes reduced in size. The actinal adambulacral spines decrease in length toward outer end of plate. They are frequently more or less flattened. One or two of the spinules on outer end of plate is usually larger than the rest.

Actinal intermediate plates each bear a tuft of spinelets, four or five in the center being considerably longer than the remainder, and resembling the more slender of the actinal inferomarginal spinelets. Some specimens have the actinal intermediate spinelets shorter and clavate, and only one or two in the center slightly enlarged, the tuft then appearing much more compact.

Mouth plates narrow but prominent. At the inner end of each plate is a diverging group of about twenty small papilliform spinelets on the edge between the actinostomial and furrow surfaces of plate. These spinelets form a several ranked series or triangular group between exposed surface of plate and peristome. On the exposed surface are two series of numerous spines extending to outer end of plate and thence decreasing in size; sometimes only one zigzag series; spines adjacent to margin much larger. Margin (adjacent to first adambulacral) has many very small spinelets, partly covering the deep fasciolar groove between the plates. The first adambulacral has a small group of spinelets, similar to those on inner face of mouth plates, between the furrow spine and first actinal. The next three plates usually have one to three spinelets in this situation. The small spinelets along the transverse margins of first seven or eight plates are more numerous than on succeeding ones.

Madreporic body entirely hidden by paxillæ. It is situated in an interbrachial angle, the outer margin being the width of two rows of paxillæ from inferomarginals. Body convex and small.

Color in life a curious neutral olive drab or pinkish gray, yellowish white on sides and actinal surface. Often some of the paxillæ are whitish, causing a mottled appearance. The color changes very little in alcohol.

Anatomical notes.—Superambulacral plates present, well developed, absent from first ambulacral ossicle. Unpaired oral plate or "odontophore" prominent, with a well-developed keel, to which is attached lower end of the free edge of interradial septum. Interradially the lower ends of ambulacral ossicles of two adjacent rays are connected by a strong muscle band, the ends themselves being separated. This allows considerable movement of mouth plates. No anus. Intestine and intestinal cœcum absent. Hepatic cœca extend two-thirds length of ray. Stomach occupies most of disk, not divided into dorsal and ventral parts. Gonads large, extending in numerous tufts depending from abactinal body wall, in linear series nearly to tip of ray. The individual bundles of tubules are rather small in specimens examined, consisting of four tubules twice dichotomously divided, making sixteen terminal tubules. Each bundle is attached to a cross ridge formed by the carinate transverse lobes of the cruciform plates. Tube feet very large, with pointed tips, and without calcareous deposits in the walls.

Variations.—Small and medium-sized specimens differ from the above in having relatively shorter rays and less conspicuous spines. For instance: R = 106 mm.; r = 16 mm.; R = 6.6 r; again, R = 45 mm.; r = 9 mm.; R = 5 r., and so on. In the first of these two specimens, the marginal spines are rather broader and shorter than in very large examples, and in the latter specimen they are only about one-half as long (relatively) and much broader in proportion. In the proximal part of ray there are but three actinal adambulacral spines and in the distal portion only two. Among the many examples of this species available, some are as small as R = 8 mm. These do not show any marginal spines, and indeed the latter do not appear in a recognizable form until R = 20 mm. Here they are scarcely to be differentiated from the other spinelets, being merely broader and flatter. I find no difficulty in separating even these small specimens from *brevispina* on the character of the latter's chaffy inferomarginal spinelets or granules and the adambulacral armature.

Two unusually large specimens were taken at stations 4203 and 4219, in Queen Charlotte Sound and Admiralty Inlet, British Columbia. In general features they agree very well with Californian examples. R = 270 mm.; r = 30 mm.; R = 9 r. In that from 4203 the paxillar granules are not so flat topped nor so crowded as in the large Californian examples and the paxillæ along central area of ray and on disk are subcircular and slightly convex, the slender marginal spinelets being in evidence. In Californian examples the central paxillæ are usually crowded, four or five sided, flat topped, and very compact in every way. In these northern specimens the marginal spines are a trifle slenderer and longer; that is, are more tapering and less obviously lanceolate, the base being the broadest part of the spine. The two spinelets which form on the inner half of the plate a continuation of the series of marginal spines are flattened, chisel shaped, and much more conspicuous than in Californian specimens, where the same spinelets are usually lanceolate. The other actinal spinelets are longer and slenderer than in the Californian examples. The same is true of spinelets of the intermediate plates. The adambulacral armature is essentially alike in specimens from the two regions. These differences are much less marked in smaller specimens, although the northern examples have slenderer and usually slightly longer spines and spinelets.

Type-locality.—Unknown.

Distribution.—Southeast Alaska (Kasaan Bay) to San Diego, California, and probably to Mazatlan, Mexico; found in 10 to 189 fathoms, usually in less than 80 fathoms; so far as known not found above lowest tide marks.

Specimens examined.—Four hundred and fifteen, from the following localities:

Specimens of Luidia foliolata examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2863	Gulf of Georgia, B. C.	87	fine sand	4	U. S. Nat. Mus.
2867	Near Flattery Rocks, Washington	37	fine gray sand	1	Do.
2870	Off Gray's Harbor, Washington	58	rocky	5	Do.
2882	Off Columbia River, Oregon	68	gray sand	5	Do.
2883	Off Tillamook Rock, Oregon	29	fine gray sand	2	Do.
2884	..do	29	.....do	1	Do.
2902	Off Santa Barbara, California	53	fine gray sand, mud	3	Do.
2906	Off Point Conception, California	96	sand and mud	2	Do.
2907	.....do	44	fine gray sand	1	Do.
2951	South of Santa Cruz Island, California	48	.....do	5	Do.
2956	South of Santa Rosa Island, California	52	.....do	1	Do.
2970	Santa Barbara Channel, California	29	.....do	1	Do.
2974	....do	73	green mud	1	Do.
3046	Off Gray's Harbor, Washington	48	fine gray sand	16	Do.
3047	.....do	50	.....do	15	Do.
3048	.....do	52	rocky	13	Do.
3049	Off Shoalwater Bay, Washington	43	fine black sand	2	Do.
3051	Off Heceta Bank, Oregon	59	coarse broken shells	2	Do.
3053	.....do	64	.....do	2	Do.
3054	.....do	53	rocks	3	Do.
3058	Off Cape Foulweather, Oregon	38	coarse gray sand, shells	1	Do.
3059	Off Siletz Bay, Oregon	77	mud	5	Do.
3060	Off Tillamook Rock, Oregon	28	brown mud	1	Do.
3061	.....do	23	fine black sand	2	Do.
3062	.....do	44	.....do	1	Do.
3063	.....do	42	fine gray sand	7	Do.
3064	.....do	46	.....do	17	Do.
3081	Off Tsiltcoos River, Oregon	61	green mud, sand	4	Do.
3083	Off Siuslaw River, Oregon	32	fine gray sand	3	Do.
3084	Off Heceta Head, Oregon	46	.....do	2	Do.
3096	Off Orford Reef, Oregon	33	stones, broken shells	3	Do.
3110	Between Golden Gate and Monterey Bay, California.	39	rocky	3	Do.
3111	.....do	20	gray sand	4	Do.
3114	.....do	62	mud	10	Do.
3115	.....do	43	fine black sand	11	Do.
3121	Off Santa Cruz, California	48	green mud, sand	2	Do.
3147	Northwest of Santa Cruz, California	56	brown mud	14	Do.
3148	.....do	47	.....do	8	Do.
3149	Off Pescadero Point, California	45	green mud	4	Do.
3152	Drake's Bay, California	36	fine gray sand	4	Do.
3153	.....do	32	green mud	8	Do.
3154	.....do	20	black sand, mud	2	Do.
3155	.....do	35	green mud	3	Do.
3167	.....do	33	.....do	2	Do.
3171	Off Russian River, California	76	rocky, sand	2	Do.
3175	Off Point Reyes, California	57	brown mud	4	Do.
3176	.....do	37	gray sand	7	Do.
3350	Off Point Arena, California	75	fine sand, mud	3	Do.
3456	Straits of Fuca, Washington	136	gray sand	2	Do.
3460	......do	53	.....do	1	Do.

Specimens of Luidia foliolata examined—Continued.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms.			
3671	Monterey Bay, California	56	green mud, sand	7	U. S. Nat Mus.
	Port Simpson, British Columbia			1	U. S. Nat. Mus., T. H. Streets.
	Puget Sound, Washington			1	U. S. Nat. Mus., Dr. C. B. Kennerly.
	Departure Bay, Nanaimo, British Columbia.			1	U. S. Nat. Mus., Geo. W. Taylor.
4203	Queen Charlotte Sound (off Fort Rupert, Vancouver Island, British Columbia).	25–30	Volcanic sand, gravel, broken shells, sponge.	1	*Albatross*, 1903.
4219	Admiralty Inlet (vicinity of Port Townsend, Washington).	16–26	green mud, sand, broken shells.	1	Do.
4243	Kasaan Bay (Prince of Wales Island, southeast Alaska).	42–47	green mud	3	Do.
4246	do	123–101	gray green mud, coarse sand, shells.	1	Do.
4347	Off San Diego, California	55–58	fine gray sand, mud	1	*Albatross*, 1904 (California).
4349	do	75–134	gray sand	1	Do.
4384	do	164–85	gray sand, rocks	1	Do.
4420	Between Santa Barbara and San Nicholas Islands, California.	32–38	fine gray sand	2	Do.
4431	Off Santa Rosa Island, California	30–41	mud, gray sand, rocks	10	Do.
4438	Monterey Bay (north of Humphack Rock), California.	41–46	fine gray sand	1	Do.
4441	Monterey Bay (between Mussel Point and Humpback Rock).	35–28	black mud, broken shells	2	Do.
4442	Monterey Bay (5 miles northeast of Monterey).	26–31	fine gray sand	1	Do.
4452	Monterey Bay (northeast of Point Pinos).	49–50	green mud	14	Do.
4453	do	49–51	dark green mud	24	Do.
4457	do	46–40	do	22	Do.
4460	Monterey Bay (11 miles off Moss Landing).	55–67	green mud	1	Do.
4464	Monterey Bay (southwest of Moss Landing).	51–36	soft dark gray mud	8	Do.
4465	do	31–21	hard gray sand	1	Do.
4467	Monterey Bay (8 miles west-northwest of Moss Landing).	54–51	soft dark green mud	7	Do.
4469	Monterey Bay (north of Point Pinos)	54–63	gray sand	1	Do.
4472	Monterey Bay (northwest of Point Pinos).	71–59	hard sand	1	Do.
4473	Monterey Bay (north of Point Pinos)	54–65	gray sand, mud	2	Do.
4474	Monterey Bay (northeast of Point Pinos).	43–34	hard sand	1	Do.
4476	Monterey Bay (southwest of Moss Landing).	25–39	soft green mud	2	Do.
4477	do	19–11	do	3	Do.
4480	Monterey Bay (10 miles west-northwest of Moss Landing).	76–53	dark green mud, sand	1	Do.
4483	Monterey Bay (6 miles west of Moss Landing).	45–44	soft green mud	2	Do.

Specimens of Luidia foliolata examined—Continued.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
4492	Monterey Bay (off Hill's Landing), California.	26	soft green mud	1	*Albatross*, 1904 (California).
4501	....do	12–11	hard sand	1	Do.
4535	Monterey Bay (3 miles off Pyramid Point).	71–54	hard gray sand	4	Do.
4548	Monterey Bay (between Italian ledge and shore).	46–54	coarse sand, shells, rocks	1	Do.
4551	Monterey Bay (near Italian ledge).	56–46	....do	1	Do.
4552	Monterey Bay (70 Fathom Bank)	73–66	green mud, rocks	1	Do.
4554	....do	60–80	....do	10	Do.
4555	....do	66–69	....do	3	Do.
4557	Monterey Bay (Portuguese Ledge).	53–54	rocks	9	Do.
4558	Monterey Bay (Humpback Rock).	40–28	....do	10	Do.
4560	Monterey Bay (off Soquel Point).	10–12	fine gray sand, rocks	2	Do.
4561	....do	15	coarse sand, shells, rocks	1	Do.
4562	....do	10–11	hard sand	12	Do.
	Mazatlan, Mexico (?)			3	Stanford University.
	San Pedro, California	13		6	University of California.

Remarks.—This is a constantly five rayed short spined species with quadrate paxillæ along either side of the abactinal surface of rays. It is entirely without pedicellariæ, and is hence sharply differentiated from *L. quinaria* and *L. limbata* of Japan, and appears to be more closely related to *L. brevispina* Lütken, of Mazatlan and the Hawaiian Islands. From this form it may be readily distinguished by the longer and more numerous inferomarginal spines, those of *brevispina* being very short and confined to the extreme margin of ray. There are only one or two of them. The other armature of inferomarginal plates consists, in *brevispina*, of numerous broad rounded squamiform granules which imbricate strongly, and along border of plates a row of very slender spinelets. The general appearance of the actinal surface in the two species is entirely different. The paxillæ are usually convex in *brevispina*, and the adambulacral armature and that of mouth plates is also very different. There are no pedicellariæ in *brevispina*. Compared with *L. clathrata* of the eastern coast of the United States, *foliolata* is seen to have much heavier and less chaffy spinelets on the inferomarginal plates, the latter being narrower and slightly longer than in *clathrata* (and *brevispina*). The marginal spines of *foliolata* are more numerous and heavier than those of *clathrata*. Both *clathrata* and *brevispina* lack the numerous minute spinelets on inner face of mouth plates. From the specimens at my disposal (one *brevispina* from Mazatlan and twelve *clathrata* from Cameron, Louisiana) I would unhesitatingly place *brevispina* much nearer to *clathrata* than to *foliolata*. The character of the abactinal paxillæ, marginal, adambulacral, and oral armature is of the same general character in the first two forms, which appear to be perfectly distinct, however.

As the list of localities will show this species is very numerous in moderate depths on a soft bottom. In Monterey Bay it is about the commonest starfish. The species is more active than any form with which I am acquainted. It progresses with ease and comparative rapidity by half walking, half swimming. The large tube feet are waved back and forth and the rays undergo a slight undulatory movement, as they are very flexible. When kept in stale water or placed in alcohol, the creature will frequently constrict off the arms near the base. These do not fall off at once, but soon break at the line of weakness where one may observe the paxillæ pulled apart as if by some violent muscular contraction.

Remains of ophiurans and several *Dentalium* shells were found in about a dozen stomachs examined, both of large and small specimens.

LUIDIA LUDWIGI Fisher.

Pl. 20, figs. 2, 3; pl. 21, fig. 2; pl. 54, figs. 2, 2*a*.

Luidia ludwigi FISHER, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 122.

Diagnosis.—Rays five. R = 107 mm.; r = 13 mm.; R = 8.2 r. Breadth of ray at base, 15 mm. Rays slender, very gradually tapering to a pointed extremity; interbrachial arcs acute; general form depressed as in other species of genus, but abactinal surface well arched; sides of ray rounded; abactinal area with three or four regular series of quadrate paxillæ on each side, the superomarginal with small two and three jawed pedicellariæ; inferomarginal plates rather narrow, arched, with one to three, usually two, lateral spines, and three to six actinal spinules larger than spinelets of general surface, and on upper end a pedicellaria similar to that of adjacent paxilla; actinal intermediate plates of interradial areas and proximal half of ray, each with a rather prominent three-jawed pedicellaria; adambulacral plates with a curved furrow spine, three actinal spines, and one or two smaller spinules.

Description.—Abactinal paxillar area is rather crowded and paxillæ of four or five regular lateral series are quadrate, although in the fourth, fifth, and sixth series (according to size of specimen) many paxillæ are subcircular or not obviously quadrate. Superomarginal paxillæ slightly smaller than those of adjacent series; paxillæ thence decreasing in size toward mid-radial area, where they are arranged without regularity and are roundish or irregular in outline. In some small specimens paxillæ are not so obviously quadrate in lateral series, being subcircular in outline, but nevertheless arranged regularly. Crown of spinelets not so flat as in *foliolata*, but rather convex, especially in small examples. Superomarginal paxillæ with about thirty-five short clavate spinelets in a radiating coordinate group, and most of them also with one or two small two or three jawed valvate pedicellaria, slightly longer than spinelets; next series with about forty spinelets, those in center of tabulum stouter than the peripheral, as in superomarginal paxillæ; small mid-radial paxillæ with about twenty spinelets, the peripheral series being much slenderer. Paxillæ decrease in size toward center of disk, being smaller there than on basal portion of ray.

Abactinal plates four-lobed as in *foliolata*, the lobes being a little shorter and thicker. Superomarginal plates with much broader lobes than adjacent abactinal series, being nearer a lozenge-shape with rounded corners. Plates imbricate by lobes forming regular transverse and longitudinal series (except on area of irregular paxillæ which have a three to five lobed base). On the distal part of ray the plates all have wider and shorter lobes, even those of the lateral series, which acquire an arcuate quadrate contour and may rarely be arcuately pentagonal. Papulæ four about each plate, large on the lateral portions of ray, very small in center, and irregular there. Papulæ are compound. Numbers of them are invaginated into body cavity and gorged with granular substance as if actively excretory. This is significant when considered in connection with the absence of an intestinal cœcum and anal pore.

Inferomarginal plates relatively narrower than in *foliolata*. Fasciolar channels deep, about as wide as the thickness of the intervening elevated ridges. Outer or abactinal end of each plate with a two-jawed (rarely three-jawed) pedicellaria similar to that of adjacent superomarginal paxilla, and with one or two, usually two, tapering sharp spines, of which sometimes the inner, sometimes the outer, is the longer; the longer (about 4 mm.) equal to about width of its plate; more rarely three shorter subequal spines in transverse series on outer end of plate. The spines form a prominent marginal fringe to ray. On actinal surface of plate three to six much shorter spinules form a transverse series in line with lateral spines, or a zigzag, or even double series, while margin of plate bears numerous unequal spinelets, becoming more capillary in fasciolar grooves. Only the outer part of the furrows is lined with the minute filtering spinelets. Considerable variation exists in the details of arrangement and number of auxiliary spinules. They are usually blunt and more or less flattened. From the actinal surface the marginal spines are decidedly conspicuous.

Adambulacral armature consisting of a curved saber-shaped furrow spine, and on actinal surface three tapering, bluntly pointed, sometimes quite slender, spines, of which one, the longest, often strongly compressed and also saber-shaped, stands behind furrow spine, and the other two form a slightly oblique longitudinal series just behind first actinal spine; or two spines, the adoral the shorter, stand in a longitudinal series just behind furrow spine, and the third just outside of the aboral (longer) spine of the series; one to three small slender spinelets occur on outer part of plate, frequently three at base of ray forming a longitudinal series, or one on adoral edge of plate, back of outer adoral spine. At base of ray the three inner actinal spines form a triangular series on margin of plate (the furrow spine being higher in furrow), and behind them are usually two or three other spines. Two spines are sometimes associated to form a sort of incipient pedicellaria.

Actinal intermediate plates of interradial region and proximal half of ray paxilliform, surmounted by a prominent three-jawed pedicellaria which is surrounded at base by numerous slender spinelets in a calyx-like whorl. Each pedicellaria is conical and one and one-half to two times as high as its width at base. The intermediate plates extend nearly to tip of ray, but on its outer third are very small and usually without spinelets. They can be seen readily if ray is soaked in caustic potash solution. Besides the primary row of intermediate plates, in each interradius there are one to five additional plates.

Mouth plates narrow, with six or seven marginal spines and seven or eight superficial ones, forming together a double series on the raised exposed surface of plate parallel with median suture. Inner spine of superficial series largest, and like the rest, slender, pointed, tapering. All spines decrease in size toward outer end of plate. Innermost marginal spine situated nearer peristome than is the enlarged inner superficial spine.

Madreporic body between second and third lateral rows of paxillæ and hidden by them.

Color in alcohol, abactinal surface dull Indian red, actinal surface and lateral spines, whitish; some small specimens with abactinal surface darker Indian red, mottled with whitish, that is, with whitish paxillæ here and there. This fades into brownish red, mottled with bleached yellow. The color washes off under a jet of water.

Anatomical notes.—Gonads in a series along either side of abactinal wall of ray as in preceeding species. Each tuft has about four short thick finger-like divisions. No anus; no intestine; no intestinal cœca. Superambulacral plates well developed, absent from first ambulacral plate. Tube feet large, with bluntly pointed tips; no calcareous deposits in their walls.

Variations.—The most conspicuous difference exhibited by small specimens (R = 27 mm.) are as follows: usually but one lateral spine (occasionally two) on outer end of inferomarginals, auxiliary spinules less conspicuous, lateral paxillæ sometimes rotund—less obviously quadrate; actinal intermediate pedicellariæ confined to interradial regions, or not extending far onto ray; abactinal pedicellariæ slightly more conspicuous than in large specimens. Spines and spinelets are slenderer in small and medium sized than in large examples.

Type.—Cat. No. 21928, U.S.N.M.

Type-locality.—*Albatross* station 2970, vicinity of Santa Barbara Islands, in 29 fathoms, on fine gray sand and mud.

Distribution.—Monterey Bay, south to San Pedro, California, in 15 to 50 fathoms.

Specimens examined.—Thirty-three from the following Californian stations:

Specimens of Luidia ludwigi examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2966	Off Santa Barbara	30	coarse mud	1	U.S.Nat.Mus.
2968	do	31	mud	1	Do.
2969	do	26	gray sand, pebbles	2	Do.
2970	do	29	fine gray sand, mud	6	Do.
4431	Off Santa Rosa Island	30-41	mud, gray sand, rocks	8	*Albatross*, 1904.
4439	Monterey Bay	42-40	gray sand, shells	1	Do.
4452	do	49-50	green mud, fine sand	2	Do.
L-2	Off San Pedro	28-24	sand, fine, mud, shells	1	University of California.
LV-1	do	23-25	mud, sand	2	Do.
LV-2	do	25-22	rocky in spots	7	Do.
LXIV-1	do	19-11	sandy, kelp	1	Do.
LXXXI-5	do	15	sand and cobbles	1	Do.

Remarks.—This species has the general form of *L. lorioli* Meissner (Mazatlan), but has longer arms, which are more attenuate distally. *L. ludwigi* lacks the conspicuous sharp spinules which are present in many of the lateral abactinal paxillæ of *lorioli*, and the latter has no abactinal pedicellariæ, such as are very characteristic of the present species. Another character which separates *ludwigi* from both *lorioli* and *bellonæ* Lütken is the presence of prominent pedicellariæ on the actinal intermediate plates of interradial region and proximal half of ray. Details of adambulacral armature differ in all three forms. *L. ludwigi* differs from *L. quinaria* in having much longer narrower rays, no scattered and abundant abactinal pedicellariæ over the midradial region, and in having three-jawed, not two-jawed, actinal pedicellariæ. The abactinal pedicellariæ of *quinaria* are low, and of the bivalved form of some Goniasteridæ. The adambulacral plates also have two-jawed pedicellariæ in *quinaria*.

LUIDIA ASTHENOSOMA Fisher.

Pl. 20, fig. 1; pl. 21, fig. 1; pl. 54, fig. 1.

Luidia asthenosoma FISHER, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 124.

Diagnosis.—Rays five. R = 86 mm.; r = 9 mm.; R = 9.5 r. Breadth of ray at base, 10 to 11 mm. Rays long, narrow, pointed, very gently tapering, with a slightly convex abactinal surface usually sunken along midradial line. General form much flattened; sides of rays rounded; inferomarginal plates narrow, not encroaching much upon actinal area, but forming rather the margin of ray, each with a transverse row of three sharp acicular spines; ambulacral furrow wide and shallow; tube feet long, in two series; actinal and marginal spines rather long and bristling, the adambulacral armature, consisting of a transverse row of three prominent spinules, forming a series in line with that of inferomarginal plates; actinal intermediate plates usually with a rather short, two-jawed, blunt, papilliform pedicellaria. Paxillæ stellate, the superomarginal about twice as large as others. Scattered two or rarely three jawed abactinal pedicellariæ are present. Prominent two-jawed pedicellaria on margin of each mouth plate.

Description.—Abactinal paxillæ with a stellate crown; those of superomarginal series larger than rest, and each corresponding to an inferomarginal plate, to upper end of which it is closely juxtaposed. Crown of superomarginal paxilla longitudinally oval (as in *sarsi*), the others subcircular. Adjacent to superomarginal paxillæ are about two regular longitudinal series of lateral abactinal paxillæ, about two of which correspond to one superomarginal paxilla. Paxillæ diminish in size very rapidly toward median line of ray and become less regular in arrangement as they approach it. Superomarginal paxilla has slightly convex tabulum armed with about thirty slender denticulate spinelets, of which about ten are scattered on surface of tabulum and the remainder about the periphery, the whole forming a diverging group. The superomarginal and other lateral paxillæ sometimes have a blunt two-jawed pedicellaria similar to but larger than those scattered over the midradial area (see below). The adjacent paxillæ have about twelve peripheral and three to five central spinelets, while those in midradial region have about ten peripheral and three or four central, very much smaller, spinelets, the whole paxilla being notably smaller. Many of small paxillæ of midradial area also bear in center of tabulum, surrounded usually by a few small peripheral spinelets, a small obovoid two-jawed valvate pedicellaria, resembling a split granule. Viewed from above, the pedicellaria is elliptical in shape when closed. Each jaw is hollowed on inner face and occasionally is larger, springing from a very low paxilla and emerging between the others. Rarely there are three jaws. Jaws of pedicellariæ much thicker and more robust than any paxilla spines.

Plates, or bases of paxillæ, are cruciform along either side of area, leaving large quadrate spaces for the papulæ. Superomarginal plates very much larger than adjacent abactinal plates, and cruciform in shape also, but with very much broader lobes, the arms on the longitudinal axis being longer than those on the transverse. Inferomarginal plates also four-lobed (as seen from the inside), there being conspicuous roundish spaces between the infero and superomarginal series, corresponding to the papular spaces on dorsal surface. Plates decrease very rapidly in size toward radial line, are irregular, frequently have five lobes, and on median radial area are roundish and crowded, without papulæ between. Thus along the radial area of ray there is a band of varying width free from papulæ.

Inferomarginal plates relatively very narrow, transversely arched, encroaching but slightly upon actinal surface, forming rounded margin to ray; chord of width equal to one and one-half times that of adambulacral and actinal intermediate plates combined. Fasciolar grooves deep and wide, slightly wider (i. e., measured on long axis of ray) than corresponding dimension of specialized elevated ridge of plate. Each plate with a transverse series of three robust, tapering, sharp spines, of which the outer is often slightly the longest, but frequently the middle one or the two are subequal; inner (actinal) spine of series is sometimes much slenderer than other two, and only one-half or two-thirds length of longest spine; latter attains a length of 5.5 mm., or slightly over one-half width of abactinal paxillar area, or nearly twice the width of plate (that is, chord of width). General surface of plate covered with slender, almost capillary spinelets, which become finer and more densely placed in fasciolar grooves, and upper end of plate sometimes bears a pedicellaria similar to those of abactinal surface.

Adambulacral plates with a slender saber-shaped furrow spine and forming a linear series with it on actinal surface, two slender, tapering, pointed spines, the inner of which is the stouter and slightly the longer. Except in small specimens, one to three very slender spinelets stand on adoral side of outermost spine, which decreases in size toward extremity of ray more rapidly than the inner.

On most of the actinal intermediate plates of proximal two-thirds of ray is a small two-jawed pedicellaria accompanied by two or three capillary spinelets; when former is absent its place is taken by about three to five capillary spinelets; jaws of pedicellaria blunt, oblong to obovate, 0.5 mm. high; three or four pedicellariæ in interradial region, but very few spinelets.

Mouth plates more like those of *Astropecten* than most species of *Luidia*. Exposed surface of combined plates, ovoid, prominent; suture between plates fairly wide. Armature consisting of a slightly tapering, bluntly pointed tooth, and back of that on margin a large two-jawed pedicellaria nearly as long as tooth. Two shorter spines may take the place of the pedicellaria. In line with the tooth a series of about ten superficial spinelets follows edge of suture, decreasing in size toward outer end of plate; and along curved margin adjacent to first adambulacral are four or five slender spinelets, the second from inner end of series often the longest. This series is separated from the superficial by a shallow groove.

Color in life, reddish brown (burnt sienna) on abactinal surface; marginal spines lighter, often whitish; actinal surface whitish.

Anatomical notes.—Superambulacral plates present, well developed, absent from first ambulacral ossicle. Gonads extend, in a series along either side of abactinal integument, to tip of ray; individual tufts short, with few thick tubules. No intestine; no intestinal cœcum; no anus. Stomach not divided into dorsal and ventral compartments. Tube feet large, pointed, without calcareous deposits in their walls.

Variations and young.—A specimen with R = 31 mm. differs from the foregoing description in having two marginal spines to plate, the third being sometimes represented by a much smaller spinule. Outer adambulacral spinelet is reduced in size, and the others are relatively longer than in the bigger specimens. Actinal intermediate pedicellariæ are confined to basal half of ray, although a few are scattered on distal portion. Abactinal pedicellariæ few or absent. A very small specimen (R = 16 mm.) has two series of marginal spines along ray, the outer spines usually the longer; actinal pedicellariæ do not extend far onto ray; paxillæ small and spaced; no abactinal pedicellariæ.

Specimens vary considerably in respect to the abactinal pedicellariæ. In the type they are numerous, but some large examples lack them on the superomarginal and adjacent paxillæ.

Type.—Cat. No. 21929, U.S.N.M.

Type-locality.—*Albatross* station 3148, off central California in 47 fathoms on brown mud.

Distribution.—From north of Monterey Bay, California, south to Los Coronados Islands, Lower California, 11 to 339 fathoms.

Specimens examined.—Seventy-one, from the following stations (California, except as noted):

Specimens of Luidia asthenosoma examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2891	Off Point Conception	233	mud	1	U. S. Nat. Mus.
2902	Santa Barbara Channel	53	fine gray sand, mud	1	Do.
2911	Cortes Bank, off San Diego	60	rocks, sand	1	Do.
2930	Near Los Coronados Islands, Lower California.	60	mud	1	Do.
2931	do	34	gray sand, shells	1	Do.
2933	do	36	fine gray sand	1	Do.
2968	Off Santa Barbara	30	coarse mud	2	Do.
2956	South of Santa Barbara	52	fine gray sand	1	Do.
3108	Between Golden Gate and Santa Cruz.	43	rocks, broken shells	2	Do.
3148	Northwest of Santa Cruz	47	brown mud	2	Do.
3478	Monterey Bay	68	gray sand	1	Do.

Specimens of Luidia asthenosoma examined—Continued.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
4310	Off San Diego	71–75	green mud, fine sand	1	*Albatross*, 1904.
4322	do	110–199	green mud, broken shells	1	Do.
4332	do	62–138	gray sand, broken shells	2	Do.
4342	Near Los Coronados Islands, Lower California.	53–66	fine gray sand	1	Do.
4343	do	55–155	do	3	Do.
4347	Off San Diego	55–58	fine gray sand, mud	1	Do.
4385	do	89–107	coarse sand, rocks	1	Do.
4421	Off San Nicholas Island	291–229	gray mud, rocks	3	Do.
4423	Between Santa Barbara and San Nicholas Islands.	339–216	green sand, shells	7	Do.
4431	Off Santa Cruz Island	30–41	fine gray sand, green mud	5	Do.
4452	Monterey Bay	49–50	green mud, fine sand	1	Do.
4457	do	46–40	dark green mud	2	Do.
4464	do	51–36	soft dark green mud	11	Do.
4476	do	25–39	green mud	1	Do.
4477	do	19–11	green mud, gray sand	1	Do.
4535	do	71–54	very hard	1	Do.
4550	do	50–64	green mud, rocks	6	Do.
4552	do	83–66	do	1	Do.
4554	do	60–81	do	3	Do.
4556	do	50–59	rocks	1	Do.
4557	do	52–58	do	1	Do.
	San Pedro	37–67	green mud	3	University of California.

Remarks.—This fragile creature bears a close resemblance to *L. sarsi* Düben and Koren, of northern Europe and the Mediterranean, and may be looked upon as a north Pacific representative of that species. None of the specimens are as large as *L. sarsi* is known to grow. The Californian species differs from *sarsi* in having very small, abactinal, two-jawed (rarely three-jawed), granuliform pedicellariæ scattered along the medioradial area, with larger ones sometimes on the regular lateral paxillæ, and on upper end of inferomarginal plates. A comparison of specimens shows that the spinelets of the abactinal paxillæ are much longer and more delicate in *asthenosoma* and the inferomarginal spines are longer. In *sarsi* the central paxillar spinelet or spinelets, in contrast to those of *asthenosoma* are stouter than the peripheral. The actinal pedicellariæ of *sarsi* taper slightly toward the tip, but in *asthenosoma* they either do not taper or the tip is broader than the base, the pedicellaria being obovate. *Luidia elegans* Perrier from off the east coast of the United States, is closely related to *sarsi,* and differs from *asthenosoma* in the structure of the abactinal paxillæ, which have the central spinelets slightly stouter than the peripheral, and all the spinelets shorter and more robust (as *L. sarsi*). The abactinal pedicellariæ are fewer than in *asthenosoma*, while the actinal pedicellariæ are longer and slenderer than in either *sarsi* or *asthenosoma* (twice or three times as long as wide). Moreover, the pedicellariæ taper very decidedly, especially on the interradial areas and proximal portions of ray.

The rays of *L. asthenosoma* drop off very readily.

Family BENTHOPECTINIDÆ Verrill, 1899, emended.

Pararchasterinæ SLADEN, *Challenger* Asteroidea, 1889, pp. xxviii, 4.
Benthopectinidæ + *Pontasterinæ* VERRILL, Trans. Conn. Acad., vol. 10, 1899, p. 217.
Notomyota LUDWIG (*Cheirasteridæ* + *Benthopectinidæ*), Sitzungsber. k. preuss. Akad. Wiss., vol. 23, 1910, p. 435.

Phanerozonia with more or less obviously alternating, convex, spiniferous marginal plates, an odd one above and below in the interradial angles of three genera; with small disk and long slender rays, and with the papulæ confined to a limited, often specialized, area at base of ray and adjacent portion of disk (or all of disk and up to three-fifths of ray). Especially characterized by the presence of a pair of muscle bands extending along the dorsal wall of the rays, from the region of the third to eighth superomarginal plates to tip. Abactinal plates without definite arrangement, either simple and flattened, with one or few spinelets, or in the form of low paxillæ, both kinds sometimes occurring in the same species. Adambulacral plates with a salient inner angle bearing a series of spinelets; one to several conspicuous actinal (or subambulacral) spines. Actinal intermediate plates few and interradial areas small. Pedicellariæ when present pectinate, fascicular, or rarely bivalvate. Anus present. No superambulacral plates. Tube feet with sucking disks. Intestinal cœcum thick,saccular, four-parted.

KEY TO THE KNOWN GENERA OF BENTHOPECTINIDÆ.

a^1. No unpaired interradial marginal plates; dorsal muscle bands sometimes attached to proximal ambulacral ossicles by a tendon.

  b^1. Paxillæ with numerous spinelets or granules.

    c^1. Papularia not two-lobed, usually more or less distended.

      d^1. Pedicellariæ when present two-jawed and occurring on the adambulacral plates; the latter with two spines on their surface .... *Pontaster* Sladen.

      d^2. Pedicellariæ fasciculate, occurring on dorsal, marginal, and actinal intermediate plates. *Pectinaster* Perrier, p. 122.

    c^2. Papularia not swollen, more or less distinctly two-lobed.

      d^1. Pedicellariæ usually present and pectinate; actinal intermediate plates always present on disk; no tuft of rather long paxillar spinelets near first superomarginal.

        e^1. Dorsal muscle bands not unusually large and not attached to enlarged crest of a proximal ambulacral ossicle; adambulacral plates with one enlarged subambulacral spine. *Cheiraster* Studer.

        e^2. Dorsal muscle bands large and attached by a prominent tendon to a specialized knob or crest of either one or two proximal ambulacral ossicles, as well as to adjacent superomarginal plates; adambulacral plates with two or more enlarged subambulacral spines; marginals very spiny.. *Luidiaster* Studer, p. 127.

      d^2. With a tuft of rather long paxillar spinelets near the first superomarginal plate; primary plates of disk each with one large spine; pedicellariæ unknown; adambulacral plates with two subambulacral spines; actinal intermediate plates absent; innermost marginal mouth spine not prolonged.. *Marcelaster* Kœhler.

  b^2. Paxillæ with usually but one spinelet, that on the primary plates of disk becoming a large spine; papularia flat, two-lobed; no pedicellariæ .... *Gaussaster* Ludwig.

a^2. Odd interradial marginal plate present in some or all of the interradii. Dorsal muscle bands not attached to a proximal ambulacral ossicle.

b^1. Abactinal plates of papular areas low tabulate and strongly stellate, the larger bearing a central conspicuous spine surrounded by a circle of more or less elongate spinelets; superomarginals with two or three and inferomarginals with two to five long bristling spines; odd interradial marginal plate not much if any more prominent than adjacent superomarginals.

c^1. Papulæ extending one-third to three-fifths length of ray; dorsal muscle bands weak; mouth plates with more than nine marginal spines each; odd interradial marginal usually absent in some of the interradii .... *Nearchaster* Fisher, p. 132.

c^2. Papulæ extending one-seventh length of ray; dorsal muscle bands strong, prominent; mouth plates with less than eight marginal spines; odd interradial present in all interradii. *Myonotus* Fisher, p. 140.

b^2. Abactinal plates flat or somewhat convex and, though frequently lobed, not strongly so, bearing a central spine only, or several spinelets in addition, or one to several small spinelets; superomarginals usually with only one large spine and inferomarginals with one or two primary spines; odd interradial marginal prominent and usually present in all interradii . . *Benthopecten* Verrill, p. 142.

Remarks.—Members of this family have a very characteristic outward "habit" and are easily identified with their group. This is due to the structure of the marginal and adambulacral plates, with their bristling armature, to the limited distribution of papulæ, and to a less extent to the simple abactinal plates which commonly have a slender central spine and a variable number of additional spinelets. They are often in the form of simple paxillæ, but all gradations between paxillæ and flat immersed plates occur. Another feature which lends a highly characteristic appearance to members of this family is the form of the pedicellariæ. When these occur they are of the double pectinate variety, or a modification of this type. That is, a comb of modified spinelets is placed opposite another similar comb, each occupying separate but closely juxtaposed plates, or the spinelets may be grouped (fasciculated) on one plate or two neighboring plates. The double pectinate pedicellariæ are strictly characteristic of this family.

Previous to Sladen's *Challenger* report (1889) the members of this family were not set apart by even subfamily distinctions from other Archasteridæ; in fact some species of *Cheiraster* and the type of *Acantharchaster* were first described as "*Archaster*." Sladen erected the subfamily Pararchasterinæ for the reception of *Pararchaster* and *Pontaster*. In 1894 Verrill split this subfamily, recognizing the Benthopectininæ for *Benthopecten*, and Pontasterinæ for *Pontaster*, *Cheiraster*, *Pectinaster*, and *Acantharchaster*. In 1899 the Benthopectininæ was raised to family rank by Verrill, and the Pontasterinæ was placed in his new family Plutonasteridæ, near *Plutonaster* and allied genera. Believing that Sladen's grouping of genera more nearly expressed the relationship, I placed the Pontasterinæ under the Benthopectinidæ in 1906. For reasons stated below the Pontasterinæ has been abandoned in this report.

The order Notomyota Ludwig (1910) is coextensive with my Benthopectinidæ and is founded primarily on the characteristic dorsal muscle bands of the rays. Ludwig recognizes two families, the Cheirasteridæ (Pontasterinæ Verrill) and Benthopectinidæ, the latter including only *Benthopecten* and *Pararchaster* restricted, hence having the limits originally set by Verrill. These two families are characterized by the absence or presence of unpaired interradial marginal plates, and by no other features of importance. In the new genus *Nearchaster*, one or more, occasionally all, the interradii have the odd marginal (not always in both series of the same interradius, however). The abactinal plates are structurally like those of *Luidiaster* and *Cheiraster* rather than of *Benthopecten*, to which the presence of odd interradials would naturally ally the genus. The dorsal muscle bands are very weak in *Nearchaster* and well developed in *Myonotus*, and are nearer to *Benthopecten* than to *Luidiaster* in the mode of attachment of the proximal ends. The very spiny marginal plates suggest *Luidiaster* rather than *Benthopecten*. Even *Benthopecten* may lack some of the odd interradial marginal plates as regularly occurs in *B. mutabilis*. In other words, *Nearchaster* stands nearly halfway between the two groups, and furnishes convincing evidence of the close relationship of *Benthopecten* on the one hand and *Cheiraster* and allies on the other. I have not maintained the two families so ably expounded by Ludwig, because I do not think a sharp line of separation can be drawn.

Whether the Benthopectinidæ should be regarded as a distinct order, the Notomyota, is wholly a matter of opinion. There are unfortunately no rules to determine what shall constitute ordinal characters. The Porcellanasteridæ are probably just as deserving of ordinal rank since they possess a set of special characters which set them apart from the other Phanerozonia. The fact that the Notomyota is not here adopted simply means that the writer has preferred to use characters of wider application. It may well be that the solution of the present unsatisfactory condition of the orders of Asteroidea will be the recognition of numerous smaller groups; about four in the Phanerozonia and two in the Spinulosa.

I have followed in the main Ludwig's arrangement of genera and species. I am not at all sure of the validity of *Marcelaster*. I have not adopted *Pararchaster*, since it is separated from *Benthopecten* by a rather trivial character, or at least by a variable and difficult one.

For a systematic and historical account of the genera and species of the Notomyota, Ludwig's paper should be consulted. Two new genera (with four new species) have been added to his list, one new form to *Pectinaster*, and two to *Benthopecten*.

Genus PECTINASTER Perrier.

Pectinaster PERRIER, Ann. sci. nat., vol. 19, 1885, art. 8, p. 70. Type, *P. filholi* Perrier. Expéd. sci. du *Travailleur* et du *Talisman*, 1894, p. 278.—LUDWIG, Sitzungsber. k. preuss. Akad. Wiss., vol. 23, 1910, p. 448.

Pontaster SLADEN (part). *Challenger* Asteroidea, 1889, p. 23.

Cheiraster LUDWIG (part), Asteroidea, 1905, p. 1.—FISHER, Zool. Anz., vol. 35, 1910, p. 551.

Diagnosis.—Benthopectinidæ lacking odd interradial marginals, with the abactinal plates a very simple form of low paxillæ, bearing numerous spinelets and with entire (not two-lobed) more or less swollen papularia; pedicellariæ when present fasciculate, confined to a single plate, or standing on two adjacent plates, occurring on actinal intermediate plates, or also on the marginals and abactinal paxillæ; marginal plates small, usually elongately oval or subtriangular in form, the two series having a tendency to alternate more or less, causing the horizontal margin that touches the companion series of plates to be more or less definitely angulated or to form two facets; actinal interradial areas with very few intermediate plates; these small and without order. Armature of adambulacral plates (1) a semicircular furrow series of small spines, and (2) one, usually larger and conical, on the actinal surface. Well-developed dorsal muscle bands, attached to one or two proximal ambulacral ossicles and adjacent superomarginals.

Remarks.—The genera *Cheiraster*, *Pontaster*, and *Pectinaster* are very closely related and have been combined in the past under the generic title of *Cheiraster* (Ludwig, 1905; Fisher, 1906, 1910). Ludwig (1910) has lately used the papularia, pedicellariæ, and subambulacral spines as primary characters for distinguishing the groups. I find also a very useful feature in the mode of attachment of the proximal end of the two dorsal muscle bands.

In *Pontaster* and *Pectinaster* the papularia are entire and swollen, while in *Cheiraster* and *Luidiaster* they are flat and two-lobed. *Pontaster* is distinguished from *Pectinaster*, in which the pedicellariæ are fasciculate and on any plates but the adambulacrals, by having two-jawed pedicellariæ on the adambulacrals only. *Luidiaster* and *Pectinaster* differ from *Cheiraster* in having the dorsal muscle bands attached to one or two of the proximal ambulacral ossicles (near where they abut against the superomarginals) as well as to the adjacent superomarginals; *Cheiraster* has the muscles attached to the superomarginals and abactinal plates, but not to the ambulacrals. *Cheiraster* has only one subambulacral spine, *Luidiaster* has two or more.

The following species is a typical *Pectinaster*, with highly specialized papularium and the maximum distribution of pedicellariæ.

PECTINASTER AGASSIZI EVOPLUS (Fisher).

Pl. 28, figs. 1, 2; pl. 55, figs. 4, 4*a*; pl. 57, fig. 1.

Cheiraster agassizi evoplus FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 551.

Diagnosis.—Differing from *Pectinaster agassizi* (Ludwig) in having abactinal and intermarginal pedicellariæ and usually larger papular areas with more numerous papular pores. Rays five; R=72 mm.; r=11.5 mm.; R=6.4+r. Nearly related to *Pectinaster filholi* (Perrier) and *Pectinaster mimicus* (Sladen). Rays long, slender, evenly tapered from the base to an attenuate extremity. General form very much as in *P. mimicus*, but rays shorter and slightly slenderer. Abactinal surface with numerous small, roundish, low, spaced paxillæ; larger ones with a delicate central spinule and a crown of eight to fifteen small spinelets, interspersed with more numerous smaller ones lacking the spinule, the former extending abundantly to tip of ray; a variable number of small pectinate or, more rarely, fascicular pedicellariæ on the abactinal surface. Papulæ confined to an oval papularium at base of ray, forty to seventy-five pores to each area in adult specimens. Accessory supermarginal spinules on first five or six plates, one to three (rarely four) accessory inferomarginal spinules on proximal third or half of ray, only one beyond, and merely the single primary spine on distal fourth of ray; adambulacral plates with five to nine furrow spinelets, and one actinal with a small companion; actinal intermediate plates extending as far as the sixth to tenth inferomarginal. Pedicellariæ numerous on interradial areas, and present on suture between marginal plates, on inferomarginals, and also sometimes between inferomarginals and intermediate plates, and between inferomarginals and adambulacrals.

Description.—Larger paxillæ of abactinal surface slightly elevated, the summit bearing an acicular, slender, very delicate spinule about 0.75 to 1.5 mm. long, surrounded at its base by about eight to fifteen radiating, very small, papilliform spinelets; the numerous smaller paxillæ, scattered between, with from one to eight equal, upright or slightly radiating similar spinelets, one often standing in the center of a circular group. Individual paxillæ clearly visible to naked eye; said to be invisible in *mimicus*. The larger paxillæ with a central spinule extend entire width of arm and to its tip. Scattered all over abactinal surface are numerous pedicellariæ formed of two to six or seven thickened spinelets, about intermediate in length between the central spinule and smaller spinelets. The spinelets of pedicellariæ are thicker than any others of abactinal surface, and form either a coordinate ("fascicular") group, or two opposing combs, usually two plates entering into the formation of a pedicellaria. Pedicellariæ are found on both large and small plates, are largest on disk, and extend to end of ray in some specimens; in others they are comparatively scarce, and lacking on outer part of ray; in a small number of examples only four or six are present, on disk. The typical form from the Galapagos to Gulf of California has no abactinal pedicellariæ.

Papularium broadly elliptical, convex, so situated that a line drawn across base of ray at interradial angle bisects it. It is about as long as half the width of ray at this point. Papulæ increase in number with age; in large specimens, forty to seventy-five to each area. The abactinal wall is much thicker on the papular areas, since the plates are here in the form of vertical rods bearing a small crown of spinelets externally (two to six or seven, with sometimes a central spinule of inconspicuous size). The rods are compressed and oriented so as to appear to radiate from larger central plates as shown in the figure (pl. 57, fig. 1). On account of the form of the plates of papularium that area is convex also on the inner or cœlomic side of the body wall. Its plates are rather closely bound together by tissue. Elsewhere the plates are thin, subcircular, and distinctly spaced, the difference in size between the large and small plates being very noticeable.

Superomarginal plates, thirty-four in an example with R=72 mm., confined to side wall of ray, much longer than high on outer part of ray, where they are nearly opposite the inferomarginals. Proximally, however, the plates are nearly or quite as high as long and are alternate with the inferomarginals. Surface of plates, sometimes with exception of a small area beneath the spine, is covered with spaced short papilliform spinelets. Each plate bears near middle of upper edge a needle-like sharp spine, the fourth from interradius longest (about 4 mm.). The first four or five plates have below this an accessory lateral spine, which in the first three or four plates is nearly or quite as long as the primary spine. A variable number of the superomarginals, beginning with the fourth to tenth, have a small pedicellaria composed of two to four stubby spinelets standing usually over the intermarginal suture, some of the spinelets, therefore, on the inferomarginals. The number of pedicellariæ is variable; sometimes only a few distal plates have them, at others fully two-thirds of the plates.

Besides a lateral prominent primary spine, slightly longer than those of superior series, the first five or six plates bear two to four unequal accessory spinules on the inner part of the plate; then beyond these a single spinule to outer third of ray.

General surface of plates covered with delicate papilliform spinelets, similar to those above, leaving partially or wholly naked a small area about the spines. Many of the plates have on the lower margin a small pedicellaria, composed of three or four spinelets. This is occasionally shared with the adambulacral or actinal intermediate plates, according as one or the other of these is adjacent. These pedicellariæ frequently occur far along the ray, but are sometimes very few in number, though not usually so.

Terminal plate tubercular, slightly wider than long, of a quadrate form, but indented on the side toward paxillar area. Distally it bears a tuft of spinelets.

Adambulacral plates with a prominently curved furrow margin bearing a series of six to eight (sometimes as few as five) slightly curved, blunt spinelets. The maximum number of furrow spinelets is probably seven, the eighth and sometimes a ninth continuing the series on the adoral margin of the plate. These two extra spinelets are really members of the furrow series so far as appearance goes. In center of plate is an upright, prominent, sharp, conical spine with usually an accessory spinule, situated between it and the adoral margin. On outer edge of plate one or two short pointed spinelets sometimes form part of a pedicellarian apparatus as mentioned above. At base of these are sometimes two actinal spinules, instead of one and a small companion.

Mouth plates with furrow series of seven or eight spinelets, of which the two or three inner are larger than the rest and the innermost largest of all. About midway between inner and outer ends of plate is a prominent, tapering, actinal spinule. A graduated uneven series of five to seven spinelets follows the median suture border but is very irregular, and sometimes there is no order at all in the disposition of spinelets, so that the armature of mouth plates is of little value for classification purposes.

Actinal interradial areas with numerous small crowded irregular plates, those adjacent to inferomarginals being smallest and most crowded. In each interradial area there are twenty-five to thirty rather large pedicellariæ, each with from two to five spiniform jaws. These extend some distance along ray on the single series of intermediate plates, sometimes straddling the suture between an inferomarginal and an intermediate plate. In interradial area the pedicellariæ occupy either one or two plates, but are conical in general form. Smaller intermediate plates without pedicellariæ usually have instead one or two slender spinelets.

Madreporic body situated about its own diameter from inner edge of superomarginal plates and surrounded by large paxillæ.

Anatomical notes.—No superambulacral plates. Dorsal muscle bands prominent and extending from about the sixth or seventh ambulacral ossicles (to which the tendon is partly attached) to end of ray. Anus present; intestinal cœcum saccular, with four divisions as in other members of this family; no very distinct dorsal stomach, merely five interradial constrictions forming a dorsal division; hepatic cœca short. Gonad confined to interradial areas. Tube feet with small sucking disks.

Young.—A specimen with R = 20 mm. (and r = 4 mm.) has the general appearance of the adult, the central spinule of the larger paxillæ being especially conspicuous. Abactinal pedicellariæ present on the disk; about ten papulæ to each area; a few intermarginal pedicellariæ; only two or three actinal interradial pedicellariæ, and none on inferomarginals or adambulacrals. Furrow spinelets, five to seven; enlarged actinal mouth spine relatively larger than in adult; furrow spinelets of mouth plates about five. Madreporic body nearly touches the marginals, only one row of paxillæ intervening.

Type.—Cat. No. 27798, U.S.N.M.

Type-locality.—*Albatross* station 4387, off San Diego, longitude of Point Conception, 1,059 fathoms, green mud.

Distribution.—Known only from southern California, 984 to 1,059 fathoms; undoubtedly ranging southward, where intergradation with *P. agassizi* is probable. Typical *agassizi* ranges from the Galapagos Islands to the Gulf of California (Ludwig, 1905).

Specimens examined.—*Albatross* station 2919, off Cortez Bank (latitude of San Diego, California), 984 fathoms, gray mud, 218 specimens; station 4387, off San Diego on longitude of Point Conception, 1,059 fathoms, green mud, 9 specimens; total, 227 specimens.

Remarks.—This form is distinguished from *mimicus*, which was dredged by the *Challenger* in the Arafura Sea, northwest of the Aru Islands, by the presence in adult and moderately young specimens of abactinal, intermarginal, and much more abundant actinal pedicellariæ. The papularia are larger and contain many more pores. For instance *P. mimicus* with R equalling 78 mm. has but a dozen pores to each papularium, while *evoplus* has forty to seventy-five. In *P. evoplus* the furrow spinelets are slenderer and curved, and the spine on the actinal surface of each adambulacral plate is not so prominent as in *mimicus*, while the proximal inferomarginals are more heavily armed than in *mimicus*.

Ludwig regards *P. forcipatus* (Sladen) as synonymous with *P. filholi* Perrier. Judging from Sladen's figures and description the papularia of *filholi* are small and the abactinal pedicellariæ have shorter spinelets and are differently formed (less pectinate than usually in *evoplus*), the paxillæ have stouter spinelets, and the central spinelet is short and conical. The paxillæ of *evoplus* are more nearly like those of *mimicus*. Other differnces to be considered are: secondary superomarginal spinule in *evoplus*, none in *filholi;* more numerous and prominent secondary spinules on proximal inferomarginal plates in *evoplus*, and the furrow spinelets longer, slenderer, and curved. Judging from Sladen's figures the actinal pedicellariæ of *filholi* have shorter and more pointed spinelets than in *evoplus*, and the intermarginal pedicellariæ of the latter are absent in *filholi* (although that species proximally has a few pedicellariæ on the vertical sutures between the superomarginals).

Through the kindness of Professor Ludwig I have received for comparison a specimen of *P. agassizi* from *Albatross* station 3366 (near Cocos Island). In this example R = 67 mm. Although the form here described is close to *agassizi*, the differences already mentioned seem sufficient to warrant its separation as a distinct race. The proximity of the known ranges of the two forms (as well as the range in depth) points to their probable intergradation. In the specimen of *agassizi* examined the papular areas are only one-half to two-thirds as large as in *evoplus* and contain only about thirty pores, whereas in the latter race there are seldom as few as forty in an equally large specimen. However, Ludwig records and figures a papularium with fifty papulæ (R=65 mm.) in *agassizi*. There are more numerous actinal pedicellariæ in *evoplus*, and in *agassizi*, as already recorded, no abactinal or intermarginal pedicellariæ. In other characters the two species are practically alike. Whatever slight differences in spine length and counts one might mention is more than compensated for by the individual variation in *evoplus*.

It will not be surprising if *mimicus*, *filholi*, *agassizi*, and *evoplus* are nothing more than races of one widely distributed species. They are all very closely related.

Genus LUIDIASTER Studer.

Luidiaster STUDER, Sitzungsber. naturforsch. Freunde, Berlin, Oct. 16, 1883, p. 131. Type, *L. hirsutus* Studer.—LUDWIG, Sitzungsber. k. preuss. Akad. Wiss., vol. 23, 1910, p. 451.

Acantharchaster VERRILL, Proc. U. S. Nat. Mus., vol. 17, 1894, p. 268. Type, *Archaster dawsoni* Verrill.—FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 549.

Cheiraster PERRIER (part), Expéd. sci. du *Travailleur* et du *Talisman*, 1894, p. 275.—FISHER (part), Bull. U. S. Fish Comm. for 1903, pt. 3, 1906, p. 1042.

Diagnosis.—Benthopectinidæ without odd interradial marginals and with the abactinal plates a simple form of low paxillæ, bearing a prominent central spine, surrounded by accessory spinules; these interspersed with secondary smaller plates, usually without central spine, bearing instead a few spinelets of varying length, always short on outer part of ray; papulæ not sharply circumscribed, but occupying entire basal part of rays, and adjacent portion of disk, and distal part of area more or less two-lobed; pedicellariæ pectinate, occupying two plates and occurring on abactinal surface, sometimes also on actinal intermediate and marginal plates; actinal intermediate plates few, spinous; marginal plates more or less alternate, very spiny; adambulacral plates with salient inner angle, and bearing a divergent group of furrow spinules and a transverse actinal row of two or more long spines. Dorsal muscle bands attached proximally to a crest of one or two ambulacral plates, as well as to adjacent superomarginals.

Remarks.—In this genus the primary abactinal plates of the papular region are roundish with faint indication of lobing. The plates are raised into a low tabulum bearing a variable number of spinules and a central movable spine.

This group differs from *Cheiraster*, its nearest relative, in having the dorsal muscle bands attached proximally to a special crest of an ambulacral ossicle, near the point where the latter abuts against the superomarginal. The muscle is attached also to the abactinal plates and superomarginals by the same tendon but the origin is on an ambulacral plate. In *Cheiraster inops* and *C. snyderi* the attachment to the ambulacral is wanting. In *Cheiraster* the papularium is more definitely circumscribed. In *L. dawsoni* the papulæ extend all the way across the ray and occupy the radial portions of disk, except at the very center.

Ludwig includes five species: *dawsoni*, *hirsutus*, *teres*, *vincenti*, and *gerlachei*. To these I would add *horridus*, described by me as a *Cheiraster* in 1906. The test as to whether all these are really congeneric will be the determination in each form of the mode of attachment of the dorsal muscle bands. I do not think *gerlachei* is congeneric with *dawsoni*, and I am skeptical also concerning *teres* and *vincenti*. I do not think *oxyacanthus* is synonymous with *dawsoni*, as Ludwig states.

LUIDIASTER DAWSONI (Verrill).

Pl. 25, fig. 2; pl. 26, fig. 3; pl. 27, fig. 2; pl. 55, figs. 3, 3*a*; pl. 56, fig. 5; pl. 119, fig. 2; pl. 120.

Archaster dawsoni Verrill, in Appendix C, On Some Marine Invertebrata from the Queen Charlotte Islands, By J. F. Whiteaves, Report of Progress; Geol. Survey of Canada for 1878-79, 1880, p. 194*b*.

Acantharchaster dawsoni, Verrill, Proc. U. S. Nat. Mus., vol. 17, 1894, p. 269.—Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 549.

Luidiaster dawsoni Ludwig, Sitzungsber. k. preuss. Akad. Wiss., vol. 23, 1910, p. 452.

Diagnosis.—Rays five. $R = 124$ mm.; $r = 22$ mm.; $R = 5.45\ r$. Breadth of ray at base, 25 mm. A narrower-rayed example: $R = 107$ mm.; $r = 21$ mm.; $R = 5.1\ r$. Breadth of ray at base, 25 mm. In the first specimen the rays taper evenly to the tip; in the second, abruptly at first, then very gradually. Interbrachial arcs of first specimen, angular; of the second, distinctly rounded. Disk small. Abactinal surface paved with small unequal plates in the form of low simple paxillæ; the larger of these plates bearing a large central articulated spine surrounded at base by a circle of small spinules (usually); the smaller paxillæ without central spine and with comparatively few divergent papilliform spinelets. Papulæ confined to disk (except center and interradial lines) and basal part of rays. Double or triple pectinate pedicellariæ of conspicuous size on dorsal surface, and one to three still larger in each interradius of actinal surface. Each pedicellaria with upward to twelve curved papillæ or spines to each group. Anus present. Marginal plates conspicuous, alternate, those of the upper series smaller than the lower, rounded, with a central eminence bearing one or two large bristling movable spines surrounded by spinules. Inferomarginals with about three large spines. Adambulacral plates with a salient furrow angle bearing a divergent group of furrow spines (about five) and a transverse actinal row of two to four long slender blunt spines. Actinal intermediate plates very few and confined to interradial region.

Description.—Abactinal area plane, or slightly swollen at base of rays. Abactinal surface paved with larger round plates interspersed with smaller more irregular ones. Viewed from the cœlomic surface these plates are seen to be irregularly arranged and close together, but not in actual contact. Papulæ are absent from center of disk, a narrow interradial line, and distal two-thirds of R. They are present, therefore, on basal part of ray and adjacent portion of disk. On this area there is some semblance to a formation of longitudinal rows by the plates of the medioradial region, and here also there is a greater difference between the two sizes of plates. The smaller plates act as connectives between the larger ones, and the large papulæ pass through the interspaces. The plates form low, simple paxillæ (protopaxillæ). The tabulum is only very slightly elevated. The large paxillæ, corresponding to the large plates, each bear a long, sharp, movable spine (sometimes two), encircled by several shorter unequal spinules (two to six or eight). On the edge of the tabulum is a circle of numerous small spinelets. Sometimes the auxiliary spinules are very few or lacking and their place is taken by small spinelets. The smaller paxillæ bear one to twelve small, slender (or thicker, papilliform), acute spinelets. The dorsal spines are largest in center of disk, being there about 5 mm. long and fairly stout. Beyond the papular area they decrease markedly in size, as may be seen from the photographic figure. There is considerable variation in the density and length of these spines, but they are never so long nor so robust as the superomarginals. The difference in size between the large and small paxillæ is better marked on disk than on the nonpapulated area of ray. On the former area, in large specimens, one may find numerous secondary plates, with a small central spinule, in the process of forming primary plates. On the proximal half of ray are from three to eight scattered pectinate pedicellariæ of conspicuous size, similar to the actinal pedicellariæ described below. Each pedicellaria is subcircular in shape, about 2.5 mm. wide, and consists of two or three primary plates juxtaposed, each plate with five or six stout, curved, blunt, specialized spinules, meeting over the common suture. (See figure.) Sometimes the pedicellariæ lie between the upper curved ends of two superomarginals.

Marginal plates of two series, alternate. Superomarginals not encroaching upon abactinal area except far along ray. Each plate strongly convex, almost tabulate, bearing one or two stout, movable, tapering spines, the uppermost the longer when two are present. These spines, which form a bristling series all along ray, are as long as the combined length of two superomarginals, and the base of each (or of the pair) is encircled by upward of twelve or fifteen slender auxiliary spinules. Outside of these on the sides of the eminence are numerous well-spaced spinelets, but the border of the plate is naked. In this way the plates of both series have the raised portions separated by naked channels. The first superomarginal spine is shorter than the succeeding ones.

Inferomarginal plates wider than superomarginals, and with central portion similarly elevated, this elevation having a transverse trend. Each bears a transverse series of three (occasionally four) rigid (though movably articulated), tapering, pointed, outstanding spines, subequal, or the uppermost or central the longest. Usually the spines are slightly stouter and often the longest is a trifle longer than the corresponding superomarginal spine. Surrounding these is a variable number of auxiliary spinules, about one-third the length of the spines, together with scattered blunt spinelets. Terminal plate small, wider than long, densely covered with spines.

Adambulacral plates wider than long, with a fairly wide suture between. Furrow margin curved, with five to seven furrow spinules, the three or four central ones as long as width of plate, slender, tapering, and blunt; the lateralmost spinelet very short as a rule. Actinal surface of plate with a transverse series of two or three long terete, truncate or blunt, rather slender spines, which are nearly as long as inferomarginal spines. On outer end of plate is often one or two much smaller spinules, and along the adoral side of the series are a number of small papilliform or squamous spinelets. In some specimens the skin covering the plates and spines is thicker than in others. In the former the spinelets often appear to have swollen tips.

Mouth plates spade-shaped, with broadly rounded actinostomial margin and rather convex surface. Marginal spines, six to eight, either tapering or untapered and blunt, the inner one or two being considerably longer than the others, which diminish rapidly in size. Seven to ten spines stand on the exposed surface of each plate, the outer three or four being often much smaller. The larger spines vary from short, thick, and blunt to long and slender. They appear to be always shorter than the corresponding adambulacral spines.

Actinal intermediate plates few and confined to the disk. Each bears a number of small spaced spinelets and usually one or two upright slender tapering spines, similar to but smaller than those of adambulacrals. In each interradius there are one to three (usually one or two) large circular pectinate pedicellariæ composed of two opposite series of eight to twelve convergent strongly incurved papilliform spinelets. Rarely there are three groups, in which case there are fewer spinelets to each. The plates bearing the pedicellarian combs usually have also one or two ordinary spines, and numerous papilliform or granuliform spinelets.

Madreporic body convex, with very irregular striæ. It is situated nearer margin than center of minor radius.

Color in life: some fresh alcoholic specimens from station 4791 showed unfaded patches of bright vermilion, where alcohol had not had free access to the surface. The tube feet seemed to be brightly colored also.

Anatomical notes.—No superambulacral plates. Tube feet in two rows; sucking disks well developed; ampullæ double; one Polian vesicle in each interradius except that of madreporic canal. Interbrachial septa membranous. Gonads confined to interradial region and opening near marginal plates. Anus present. Intestinal cœcum large, with four thick lobes. Passage from cœcum into dorsal stomach short and narrow. Stomach not clearly divided into dorsal and ventral portions. Retractors of stomach well developed; cœca extending only a short distance into arm. No calcareous particles in tube feet or walls of stomach.

The two muscle bands on the cœlomic surface of the dorsal integument are remarkably well developed. The tendon is attached to a special crest of the seventh and eighth ambulacral ossicles, and also to the inner surface of the adjacent (third) superomarginal. The tendon is about 9 mm. long, and the heavy muscle band which immediately becomes attached to the dorsal integument tends slightly inward, broadens a little and at about one-third R, joins the muscle of the other side. The two run parallel, and closely joined to tip of ray, occupying the width of the narrow paxillar area. Professor Ludwig has kindly sent me preparations of *L. hirsutus*, which show that the muscles are similarly attached in that species. This character is useful, for some species of *Luidiaster* are superficially like *Cheiraster*.

Variations.—The chief variations have been considered in the foregoing description. These concern the relative length and number of dorsal spines and their accompanying spinules, the superomarginal and adambulacral spines, and the pedicellariæ. Both actinal intermediate and abactinal pedicellariæ are always present, but variable in number. Some specimens have more numerous auxiliary spinules surrounding the dorsal spines than others, and the accompanying miliary spinelets are subject to considerable variation in length and number. The armature of the marginal plates is essentially of the same character as that of the large paxillæ or dorsal plates. Large specimens from station 3320 and station 3223 have broader rays than examples from deeper water, as for instance, station 3339. This variation is probably not correlated with depth, as examples from station 4792 have rather narrow rays.

Young.—The smallest specimen has R = 12.5 mm.; R = 3 r. There are no papulæ, and one would refer it without hesitation to *Cheiraster*. Large abactinal spines undeveloped, and madreporic body adjacent to superomarginals; unlike the adult, the superomarginals encroach conspicuously on abactinal area; one superomarginal and two inferomarginal spines, the auxiliary spinules being nearly as long as spines. Furrow spines, three to five; actinal adambulacral spines, two. Two interradii have each a pedicellaria;[a] no abactinal pedicellariæ (station 4784).

Another larger example, same locality, has R = 25 mm., R = 5 r. Some of the dorsal spines have appeared on disk; only two or three papulæ; madreporic body still near margin; marginal spines relatively longer; pedicellaria in each interradius. A specimen from station 3223, with R = 40 mm., has acquired abactinal pedicellariæ; and the dorsal spines, though fewer than in adult, extend all along the ray. The papulæ are confined to base of ray, are few in number, but area extends all the way across ray. Dorsal muscles well developed. An example with R = 56 mm., R = 5 r, has the same appearance as the very large specimens, except that the papular area is not so extensive nor the dorsal spines so numerous, and the madreporic body is nearer to margin.

Type.—In the Yale University museum.

Type-locality.—Off Queen Charlotte Islands, 111 fathoms.

Distribution.—Bering Sea (Pribilof, Aleutian, and Commander Islands), south along the coast of Alaska to Queen Charlotte Islands, British Columbia, in 56 to 159 fathoms.

Specimens examined.—Forty-two, from the following stations:

Specimens of Luidiaster dawsoni examined.

Station.	Locality.	Depth.	Character of bottom.	Number.	Collection.
		Fathoms.			
2842	Near Unalaska, Alaska	72	pebbles	1	U. S. Nat. Mus.
2853	South of Kadlak, Alaska	159	gray sand	1	Do.
3223	Near Unalaska, Alaska	56	black pebbles	11	Do.
3225	do	85	black sand	1	Do.
3320	do	59	do	1	Do.
3339	East of Shumagin Islands, Alaska	138	mud gravel	2	Do.
3500	Near St. George Island, Bering Sea	121	fine gray sand, gravel	1	Do.
4784	Near Attu Island, Aleutians	135	coarse pebbles	3	*Albatross*, 1906.
4790	Near Bering Island, Commander Islands.	64	pebbles	2	Do.
4791	do	76	rocky	5	Do.
4792	do	72	pebbles	14	Do.

Remarks.—Ludwig (1910) has placed my *Cheiraster horridus* from the Hawaiian Islands under the present species. It is, however, distinct, and if compared with an equal sized specimen of *dawsoni* presents the following differences. Compare also pl. 17, fig. 3, Starfishes of the Hawaiian Islands, with pl. 119, fig. 2, this report.

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[a] The young of *Acantharchaster* was stated by me (Bull. U. S. Fish Comm. for 1903, pt. 3, p. 1043) to be without pedicellariæ. The specimens I had then were the young of *Nearchaster variabilis*.

Horridus.	*Dawsoni.*[a]
Abactinal paxillæ of disk frequently with accessory spinules one-half as long as spine.	Abactinal paxillæ without elongated accessory spinules.
Madreporic plate situated its own diameter distant from superomarginals.	Madreporic plate nearly touching superomarginals (in young specimens only).
No pedicellariæ.	A large pectinate pedicellaria on most or all of the actinal interradial areas.[b]
Mouth plates with three slightly enlarged actinal spinules.	Mouth plates with about four very prominent actinal spines (as long as the proximal subambulacral spines) parallel to furrow series.

Luidiaster oxyacanthus (Sladen) differs from *dawsoni* in the following particulars: in *dawsoni* the paxillæ bearing special central spines extend to end of ray, only onto base in *oxyacanthus; dawsoni* frequently has two superomarginal spines, rather than only one; furrow spinelets longer, slenderer, and the series with a longer base line than in *oxyacanthus;* the subambulacral spines longer and frequently three (nearly as long as the inferomarginal spines); actinal intermediate pedicellariæ larger, each comb having eight to twelve spinelets (about five in *oxyacanthus*); mouth plates with more abruptly enlarged inner teeth and seven to ten spines on the actinal surface (about five in *oxyacanthus*). The disk of *oxyacanthus* is smaller than in *dawsoni* and the interbrachial angles more abrupt, less rounded.

Genus NEARCHASTER Fisher.

Acantharchaster FISHER (part), Zool. Anz., vol. 35, March 29, 1910, p. 549.

Nearchaster FISHER, Ann. and Mag. Nat. Hist., ser. 8, vol. 7. Jan., 1911, p. 91. Type, *Acantharchaster aciculosus* Fisher.

Benthopectinidæ with the odd interradial marginal plate lacking in from one to four interradii, though sometimes present in all; not always present in both series of the same interradius; abactinal plates large and small intermingled, the large primary plates bearing on a low tabulum a long sharp spine surrounded by a circle of accessory slender spinules, variable as to number and length—sometimes over half as long as the primary spine; secondary plates with a group of shorter spinelets; primary plates of papular areas strongly stellate; papulæ not in circumscribed areas, but distributed all over disk (except sometimes the very center) and along ray from one-third to three-fifths its length, being confined to either side of the paxillar area distally; rays very long and slender; marginals extremely spiny—two or three long, sharp superomarginal spines and two to five inferomarginals; subambulacral spines one to three, usually two, long; furrow spines one to seven; mouth plates large, with numerous marginal spines, those of each pair of plates disposed in three independent series: the median teeth which are the largest and fewest, and on either side a series of smaller spines subequal or graduated in length toward the mesial members of the group; pedicellariæ when present large, pectinate, on any or all of the following plates: abactinals, inferomarginals, actinal intermediates; dorsal muscle bands not attached to an ambulacral ossicle, rather weak.

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[a] Taken from immature specimen; a large specimen would vary slightly from this. The type of *horridus* is an immature form, in all probability.

[b] Erroneously stated by me to be lacking in young *dawsoni*. The specimen examined then turns out to be young *Nearchaster variabilis*. The attachment of the muscle bands is unknown in *horridus*.

Remarks.—This genus agrees with *Benthopecten* in having long rays and odd interradial marginal plates. It differs in possessing usually more extensive papular areas, in having much more spiny marginals, and abactinal plates, which instead of being flat and often immersed, are tabulate and paxilliform, bearing numerous spines of conspicuous length.

Superficially the most striking feature of *Nearchaster* is this dense armament of abactinal spines, springing from low tabulate plates which in their essentials are like those of *Luidiaster dawsoni*. The species show more outward resemblance to *Luidiaster* than to *Benthopecten* in spite of the presence of one or more odd interradial marginal plates.

KEY TO THE SPECIES OF NEARCHASTER.

a^1. Abactinal accessory spinules long and slender, forming with the primary spines a dense armament; secondary plates with long spinules; furrow spinules one to three; papulæ extending to middle of ray...*aciculosus*, p. 133.

a^2. Abactinal accessory spinules not greatly developed in length or number; if developed at all only two or three around each spine; secondary plates with short spinelets; abactinal integument firmer and plates closer together; furrow spinules four to seven.

- b^1. Numerous abactinal pectinate pedicellariæ together with inferomarginal and actinal intermediate pedicellariæ. Disk larger. Twenty adambulacral plates to ten inferomarginals; papulæ extending as far as twenty-eighth to thirty-fifth superomarginal.............*pedicellaris*, p. 138.
- b^2. Very few abactinal pectinate pedicellariæ and only exceptionally actinal or inferomarginal ones. Disk smaller. Twenty-two adambulacral plates to ten inferomarginals; papulæ extending as far as ninth to twenty-third superomarginal....................................*variabilis*, p. 137.

NEARCHASTER ACICULOSUS (Fisher).

Pl. 24, fig. 1; pl. 26, figs. 1–3; pl. 55, figs. 1, 1*a*, 1*b;* pl. 56, fig. 3; pl. 118, fig. 3.

Acantharchaster aciculosus FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 550.
Nearchaster aciculosus FISHER, Ann. and Mag. Nat. Hist., ser. 8, vol. 7, Jan., 1911, p. 92, figs. 1, 3, 5.

Diagnosis.—Rays five (very rarely six). R = 146 mm.; r = 16 mm.; R = 9 r; width of ray at base, 19 mm. Cotype: R = 217 mm.; r = 16 mm.; R = 13.5 r; width of ray at base, 19 mm. This is the longest-rayed specimen, station 4381. Rays very long, slender, flexible, and tapering gradually from narrow base to attenuate extremity. Abactinal surface covered with stellate plates of two general sizes, large primary plates bearing a raised tabulum with a central, long, slender, movable needle-like spine surrounded by a circle of eight to fifteen divergent, very slender, seta-like spinules one-third to over one-half the length of spine; interspersed among these, smaller plates with spinules only, or perhaps an incipient central spine; beyond middle of ray, plates with a uniform covering of minute spinelets, three or four to a plate; a few abactinal pectinate pedicellariæ. Papulæ numerous, large, distributed all over disk and on ray to about two-thirds R from center. Superomarginals with two or three long, slender, movable spines, surrounded by seven to twelve auxiliary spinules; inferomarginals similarly armed; about three or four (as few as one, or sometimes all five) interradii with an odd marginal plate, bearing one or two spines, in both series, but not always corresponding; an odd superomarginal sometimes opposite paired interradial inferomarginals. Adambulacral plates with two to four furrow spinules, and two or three long, slender actinal ones in oblique series. Mouth plates broadly spade-shaped with nine to fifteen marginal spinules, subequal except for the inner one or two, which are enlarged to form teeth. Typically no actinal pedicellariæ; exceptionally these may be present in northern examples.

Description.—Abactinal surface weak, paved with fairly large, strongly stellate, rather loosely joined plates, interspersed irregularly with fewer smaller-lobed or entire, irregular secondary plates. Beyond about the basal third of ray the plates lose the lobes, become rapidly smaller and roundish or irregular, and, where there are no papulæ, closer together. The large plates of the disk and basal part of ray have five to nine unequal lobes, the secondary plates three to five or none. Papulæ numerous and large, distributed all over disk (except a very narrow interradial area near margin) and on ray to about two-thirds of R. Beyond about one-third R the papulæ are confined to the sides of the abactinal area, the medioradial region being free from them.

Each primary abactinal plate is raised into a low circular tabulum, bearing on its center a very long, slender, sharp, movable spine, the longest being 8 to 11 mm. in length (or about one-half to two-thirds width of ray at base). Each large spine is surrounded, on edge of tabulum, by a circle of eight to fifteen straight, very slender, unequal, divergent, seta-like spinules, about one-third to over one-half the length of spine. The small plates bear a group of divergent spinules only. In typical specimens the whole surface of disk and proximal third of ray is a mass of extraordinarily slender spinules, the primary spines rising above the more delicate armament. Beyond the region of abundant papulæ (basal third). on ray the primary spines rapidly become fewer and smaller, and the secondary spinules also diminish in number and size, while the secondary plates have a few short, very delicate spinelets. Beyond, about the middle of ray, all plates are armed with three or four of these short delicate spinelets, forming a uniform nap. A few pectinate pedicellariæ, with two opposing combs of four to ten slender sharp spinelets, are scattered here and there over the papular area.

Marginal plates of two series alternate on proximal part of ray, but farther along they are less evidently so. Plates of both series rather thin, longer than wide, and with central spiniferous prominence. Superomarginals numerous (upward to eighty-five), confined to side of ray on proximal part, but encroaching more farther along. Typically each plate bears two or three long, slender, movable, bristling, pointed spines in a vertical series, surrounded by a circle of seven to twelve auxiliary spinules of very variable length and robustness. In addition there are a few minute scattered thornlets. There are from two to five odd interradial superomarginals, specimens from the same station varying in this respect. One of the first superomarginals of an interradius grows at the expense of its neighbor, which is crowded out of place. Sometimes it is difficult to determine whether such a plate is prominent enough to be considered "odd." Usually about three or four interradii have the odd plate (bearing usually one large spine, a smaller companion, and several spinelets). The interradial plates, whether single or double, project above the tops of the others. The superomarginal spines are longer and stouter than the abactinal ones.

Inferomarginals larger than superomarginals, and like them very convex, the prominence bearing a bristling group of two or three long spines (similar to but slightly shorter than those of superomarginals) surrounded by about ten unequal spinules, a few of which are often considerably longer than the rest, especially near the base of ray. There may be no odd interradial inferomarginals, or from one to four. In the cotype there are two, and one in the process of becoming "odd;" in the type only one. An odd interradial superomarginal may have paired inferomarginals, corresponding to it, and vice versa. The odd or interradial unpaired marginal is a very variable character in this species, specimens from the same station differing widely. Age seems to have something to do with its presence, and northern specimens are more constant in having the maximum number. Typical examples of this species lack marginal pedicellariæ.

Adambulacral plates wider than long, with slightly angular furrow margin. Armature a palmate furrow series of two, three, or four slender, unequal, spinules, of variable length, and on the actinal surface of plate near the inner edge, an oblique series of two, varying to three, long, slender spines. The figures will give a better idea than description. The inner actinal spine (especially when three are present) sometimes stands on the furrow margin and seems to form part of the furrow series, the spine being then very disproportionate in size. In northern examples (Washington coast) only one furrow spinule is frequently present. A few minute thornlets stand here and there about the large spines; otherwise the surface of the plates is bare.

Combined mouth plates broadly spade-shaped with a semicircular inner margin, and a convex actinal surface. Each plate bears a furrow comb of nine to thirteen, rarely fifteen, untapered, blunt spinelets of nearly equal length, except the innermost one or two, which are considerably enlarged. On the exposed surface of each plate three to six spaced, long, slender, sometimes flat-tipped, spines form an angular series.

Actinal intermediate plates few, confined to interradial region, and armed with one or two slender spines (like those of adambulacral plates), with a few accompanying spinules, or with only a very few spinules, or with minute spinelets simply. Northern specimens may occasionally have a small pectinate pedicellaria in one or two of the interradii. This is typically absent.

Madreporic body convex, subcircular, situated less than half its own diameter from margin. Ridges irregularly radiating, branched; striæ interrupted.

Color in alcohol, whitish.

Anatomical notes.—No superambulacral plates. Gonads confined to interradial regions and opening close to first superomarginal plate. Anus small; intestinal cœcum similar to that of *Luidiaster dawsoni*, a sac with four radiating obtuse lobes, opening into stomach, inconspicuous, though fair-sized; no distinction between dorsal and ventral stomachs; hepatic cœca extending into rays about two or three *r*. Double ampullæ; tube feet large, in two rows, with sucking disk; one Polian vesicle in each interradius except that of madreporic canal. No calcareous particles in tube feet, ampullæ, walls of stomach, or gonad. Dorsolateral muscles weak, forming two inconspicuous bands on outer part of ray.

Variations.—The principal variations have already been noted in the foregoing description. The rays increase considerably in length with age. Generally speaking, the spinulation is more developed in southern than in northern specimens, especially the secondary abactinal spinules. Northern specimens have, as a rule, more of the interradii, with an odd upper and under marginal plate, the full complement being common; southern examples have usually two to four, seldom five.

Fully half the specimens from station 3347 have one or two pectinate pedicellariæ in one or more of the actinal interradial areas and between several of the proximal inferomarginals. The auxiliary spinules surrounding the abactinal primary spines are fairly long, but are poorly developed on the secondary intermediate plates.

Young.—Very young specimens (station 4407) have short rays, a large terminal plate, fewer spines than adult, and no papulæ. The smallest example has R = 6.5 mm., r = 2 + mm.; six superomarginals; two interradii, with an odd superomarginal; one superomarginal spine, no abactinal spines, a group of three to five spinelets to each plate, one or two inferomarginal spines, one furrow spinelet, one or two actinal adambulacral spinules, six marginal mouth spinelets, three on surface of plate; no actinal intermediate plates. In general, the specimen resembles a young *Cheiraster* with two odd marginals. An example as small as R = 38 mm. is sufficiently like the adult to make identification easy. The characteristic abactinal plating and spinulation is very evident, and the actinal armature is essentially like that of adult; but the rays are short and the papulæ restricted to disk and proximal fourth of R.

Type.—Cat. No. 27799, U.S.N.M.

Type-locality.—*Albatross* station 4402, between San Diego and San Clemente Island, California, 542 fathoms, green mud.

Distribution.—From south of the Alaska Peninsula to northern Lower California, in about 300 to 800 fathoms, usually in about 500 to 700 fathoms; principally on green mud.

Specimens examined.—Ninety-two, from the following stations:

Specimens of Nearchaster aciculosus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2871	Off Gray's Harbor, Washington	559	brown ooze	2	U. S. Nat. Mus.
2923	Off San Clemente Island, California	822	green mud	1	Do.
2980	Off Anacapa Island, California	603	do	5	Do.
3070	Off Sea Lion Rock, Washington	636	do	4	Do.
3073	do	477	do	1	Do.
3338	Vicinity Shumagin Islands, Alaska	625	green mud, sand	3	Do.
3343	Off Destruction Island, Washington	516	green mud	24	Do.
3347	Off Cascade Head, Oregon	345	mud	14 var.	Do.
3670	Off Monterey Bay, California	581	green mud, sand	1	Do.
4335	Southwest of San Diego, California	500–524	green mud, fine gray sand	1	*Albatross*, 1904.
4352	Vicinity of San Diego	549–585	green mud	1	Do.
4353	do	628–640	do	7	Do.
4354	do	642–650	do	3	Do.
4381	Vicinity of Los Coronados Islands, southwest of San Diego.	618–692	do	1	Do.
4398	Between San Diego and San Clemente Island, California.	620	green mud, rocks	1	Do.
4400	do	500–507	green mud	5	Do.
4402	do	542	do	12	Do.
4405	Between San Clemente and Santa Catalina Islands, California	654–704	do	2	Do.
4407	do	334–600	rocks, shells, fine gray sand	3	Do.
4421	Between Santa Barbara and San Nicholas Island, California.	241–298	green mud, rocks	1	Do.

NEARCHASTER VARIABILIS (Fisher).

Pl. 24, fig. 2; pl. 27, fig. 4; pl. 55, figs. 2, 2*a;* pl. 56, fig. 4; pl. 119, fig. 1.

Acantharchaster variabilis Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 550.

Diagnosis.—Resembles *N. aciculosus*, but differs in having a firmer abactinal integument, with closer-fitting plates; in the reduction of the spinules surrounding abactinal primary spines, these being either very short, or, when lengthened, comparativey few and and not forming a dense chevaux-de-frise; in having short accessory marginal spinules; in having, as a rule, proximally four to six (instead of one to three) furrow spinules; and in the variable extent of papular area on ray (one-third to three-fifths length of ray). As this species is a close relative of *aciculosus*, the description will be more intelligible if in the form of a comparison.

Description.—The spines are usually stouter than in typical *aciculosus*. The accessory abactinal spinules, which form such a characteristic armament in *aciculosus*, are here reduced greatly in length, in extreme cases forming a ring of insignificant spinelets about the bases of the primary spines and a small paxilliform group on the secondary plates. Sometimes a few, or rarely nearly all, are lengthened on part of the primary plates, but never on all, nor on the secondary plates except very unequally and rarely. The papulæ are distributed all over disk except for a narrow median interradial line, and extend along the ray a variable distance, ranging from the ninth to the twenty-third superomarginal, or for about one-third to three-fifths the total length measured along the side. Distally the papulæ are confined to a rather narrow band on either side of the median radial area, and near the tip of these bands the papulæ are often few and rather widely scattered. Abactinal pectinate pedicellariæ very few or absent. The armature of the marginal plates follows the reduction seen on the abactinal plates. The accessory spinules are small and weak and clustered about the base of the three primary spines. Some of the latter on inferomarginal plates may have flattened tips. Odd interradial superomarginals three to five, more often four or five than three. Interradial inferomarginals usually fall one behind the superomarginals.

Adambulacral furrow spines proximally three to six, distally three to five, slender, blunt, the two, three, or four central spines of the series the longest, and proximally longer than width of plate. In the type there are five or six furrow spines proximally, of which the three or four centralmost are the longest. In specimens from station 3330 there may be three, four, or five furrow spines, somewhat shorter than in type. Subambulacral spines, two, sometimes three, or very rarely four on the first few plates, long, slender, blunt, in a diagonal transverse series, the longer, blunter outer spine being on the adoral side of the plate. The outer spine is about three times as long as width of plate, or proximally two and one-third to two and one-half times as long as longest furrow spine; the inner slightly shorter. An aberrant specimen from station 3330 has only one subambulacral on most of the distal adambulacral plates. Along adoral border of plate are a few very small spinelets. There are eleven to thirteen marginal spines on mouth plates, of which the two inner are abruptly longer; five to seven long spines stand on the actinal surface, forming a triangular group.

Madreporic body very convex with irregular striæ and situated, as a rule, about its own diameter distant from margin. Measurements of type: R = 175 mm.; r = 15 mm.; R = 11.6 r. Breadth of ray at base 19 mm.

Variations.—The principal variations have already been stated in the foregoing description. These are so striking in certain particulars that it has been difficult to decide whether the specimens belong to one or two species. In the type the papulæ extend along the ray as far as the thirteenth to sixteenth superomarginal plates, while in two specimens from station 3330 they reach as far as the twenty-third, in one other to the eighteenth and in another to the fourteenth, forming a pretty regular transition. In a small specimen from station 4238 the papulæ reach to the eighth superomarginal, and in a full grown example (no locality) as far as the ninth to twelfth plate. In the large examples, therefore, the variation is between nine and twenty-three, the type being between the two extremes. The specimens from station 3330 are otherwise aberrant in having usually only four, or three and four (but in one case five), furrow spinules proximally, and one specimen has only one subambulacral spine distally. This last example has two to six inferomarginal pedicellariæ proximally, and rather more than the normal number abactinally. The two varieties intergrade so perfectly and the differences in spinulation alluded to are so inconstant that I have regarded the specimens as belonging to a single species.

Type.—Cat. No. 27800, U.S.N.M.

Type-locality.—*Albatross* station 3331, north of Unalaska, 350 fathoms, mud.

Distribution.—Southern Bering Sea to southeastern Alaska, 108 to 351 fathoms; in shallower water than *N. aciculosus.*

Specimens examined.—Ten; *Albatross* station 3330, same as type-locality, 351 fathoms, black sand, mud, four specimens, U.S.N.M.; station 3331, type-locality, 350 fathoms, one specimen, U.S.N.M.; station 3608, Bering Sea between Unalaska and St. George Island, 276 fathoms, gray sand, U.S.N.M. one specimen; one specimen without locality, probably Bering Sea, U.S.N.M.; station 4230, vicinity of Naha Bay, Alaska, 240 to 108 fathoms, rocky, one specimen, *Albatross*, 1903; station 4238, vicinity of Yes Bay, 229 to 231 fathoms, mud, rocky, two specimens, *Albatross*, 1903.

Remarks.—The specimens ranged under this species differ from *aciculosus* in having much less conspicuous abactinal accessory or auxiliary spinules and a papular area of variable extent on the rays. The absence of long accessory abactinal spinules gives *variabilis* a very different facies from the preceding form.

From *pedicellaris*, which I first believed to be a subspecies, *variabilis* differs in lacking the numerous inferomarginal and abactinal pedicellariæ, and in the variable and less extensive papular areas. The disk of *pedicellaris* is larger and the accessory spinules more numerous and longer, giving the abactinal surface an appearance only slightly less bristling than that of *aciculosus.*

NEARCHASTER PEDICELLARIS (Fisher).

Pl. 23, fig. 4; pl. 25, fig. 1; pl. 27, fig. 3; pl. 118, fig. 2.

Acantharchaster variabilis pedicellaris, FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 550.

Diagnosis.—Resembling *A. variabilis* but differing in having a large number of abactinal pectinate pedicellariæ which are scattered all along ray; in the presence of numerous inferomarginal and usually one or two actinal interradial pedicellariæ; in the constantly extensive papular areas; in the typically larger disk. R=168 mm.; r=22 mm.; R=7.6 r.; breadth of ray at base, 26 mm.

Description.—The dorsal pectinate pedicellariæ are scattered thickly over the abactinal area, extending far along ray, especially near the marginal plates. The perfect pedicellariæ of disk and proximal portion of ray consist of two combs, each with about twelve tapering sharp, convergent spinelets. Smaller plates have often only three spinelets to a comb, and sometimes there is one comb without an opposing companion. The accessory or secondary spinules (five to eight) are very unequally developed on primary plates. Only two or three may be developed to any size, these occasionally attaining the length of the primary spine, while the rest are successively shorter; or two, three, or four accessory spinules are developed to one-half or more of the length of the primary, and no other spinelets are present on plate; or, the spinules are short and form a ring around the base of the spine. Many of the largest plates have a number of small spinelets in addition to the accessory spinules. The secondary plates have a rudimentary central spine, with a few small spinules, or else the latter only.

Papulæ very numerous, all over disk, and extending along ray as far as the twenty-eighth to the thirty-fifth superomarginal, or beyond middle of ray. Beyond about the fourteenth or fifteenth superomarginal they are confined to either side of median radial area.

Three specimens have five odd interradial superomarginals, one has four, and one has two. The spines of the marginals are similar to those of *variabilis*. Some of the proximal inferomarginals have four or five subequal slender, tapering, blunt spines in addition to six or more shorter accessory spinules; over most of the ray there are three primary spines, and distally two. The accompanying accessory spinules are conspicuous, four or five, or sometimes more; occasionally two or three are nearly as long as the primaries. In addition, small-spaced spinelets are present, especially on actinal surface of plate. The first few superomarginals (as well as inferomarginals) have a vertical single or double series of six or eight accessory spinules, in addition to two or three stout, long, sharp primary spines (near end of ray only one). Farther along ray the accessory spinules are slenderer and shorter, seven or eight in number and grouped around the longer spines. In addition to these are several small scattered spinelets in a ring, outside the spinules. On the vertical suture between many of the inferomarginals, but of irregular occurrence toward end of ray, is a conspicuous pectinate pedicellaria with two opposing combs of about twelve slender spinelets. The actinal interradial areas have usually one or two large pedicellariæ and a few rather long spinules.

The adambulacral plates have a palmate furrow series of about six or seven slender, untapered, round-tipped spinules, the two or three central ones longer than width of plate and the others graduated on either side, the lateralmost spinelet being very short. Not quite typical examples have five furrow spinules. There are usually two (proximally three) slender, long, truncate spines in a diagonal transverse series on the actinal surface of each adambulacral, the outer being slightly the longer, and situated nearer the adoral margin of plate. These spines are proximally about two and one-half times as long as width of plate.

Mouth plates of the same shape as in *variabilis,* with eleven or twelve to sixteen furrow spinules, the innermost two being abruptly enlarged to form teeth; the others form an independent comb and are subequal or the mesial a trifle the longest. Five to seven spines stand on the surface of the plate, four or five parallel with the suture margin and the rest between them and the free margin, forming thus a triangular group.

Type.—Cat. No. 27801, U.S.N.M.

Type-locality.—*Albatross* station 3337, south of Unimak Island, Alaska, 280 fathoms, green mud, rocks.

Distribution.—Known only from type-locality.

Specimens examined.—Four from the type-locality and two without labels.[a]

Remarks.—Typical examples of this species have the secondary or accessory abactinal spinules about intermediate in point of development between *aciculosus* and *variabilis.* The species differs from *aciculosus* in the presence of numerous pedicellariæ, more numerous furrow spines, and stouter spines generally, as well as larger disk. The madreporic body is situated more than its own diameter from the margin in *pedicellaris;* less than its diameter in *aciculosus.* The more extensive and constant papular areas, the numerous abactinal pedicellariæ, and slightly more numerous furrow spines will serve to distinguish *pedicellaris* from *variabilis.* In *pedicellaris* there are twenty adambulacral plates to the first ten superomarginals (not counting the odd interradial); in *variabilis* there are twenty-two; in *aciculosus,* nineteen or twenty.

Genus MYONOTUS Fisher.

Acantharchaster Fisher (part), Zool. Anz., vol. 35, March 29, 1910, p. 551.

Myonotus Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 7, Jan., 1911, p. 91. Type, *Acantharchaster intermedius* Fisher.

Diagnosis.—Benthopectinidæ similar to *Nearchaster* but differing in having the papulæ confined to the disk and proximal seventh of ray; in the comparatively few marginal mouth spines, regularly graduated in length toward the inner teeth, and in the very stout dorsal muscle bands; marginal plates very spiny (two or three superomarginal and at least three inferomarginal spines); primary abactinal plates of papular areas strongly lobed and in the form of tabulate paxillæ, bearing a large central spine, and a circle of small spinelets on the tabulum; odd interradial marginals present in all interradii, the unpaired superomarginal not conspicuously larger than neighboring plates, and its spines not larger than succeeding superomarginal spines; adambulacral furrow spines one to three, long; subambulacral spines, two.

Remarks.—This genus resembles *Nearchaster* in the following points: very spiny marginals; general structure of the lobed, tabulate, spiny, primary abactinal plates; the rather inconspicuous odd interradial marginals, these not being prominent as in *Benthopecten,* nor having more conspicuous spines than the other superomarginals. It differs from *Nearchaster* in having the papulæ confined to the disk and proximal seventh of ray, in having much stouter dorsal muscle bands, and mouth plates with few marginal spines regularly graduated in length toward the inner teeth.

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[a] Bottle broken by earthquake, 1906.

Myonotus differs from *Benthopecten* in having prominent paxillæ bearing on the tabulum a central movable spine and a circle of accessory spinelets, in not having the odd interradial marginal plates and spines more prominent than the other superomarginals, and in having much more numerous and conspicuous marginal spines.

MYONOTUS INTERMEDIUS (Fisher).

Pl. 24, fig. 3; pl. 27, fig. 1; pl. 118, figs. 1*a*, 1–1*f*.

Acantharchaster intermedius Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 551.
Myonotus intermedius Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 7, Jan., 1911, p. 92, figs. 2, 4.

Diagnosis.—Resembling in general appearance a long-rayed *Luidiaster* with odd interradial marginals. Characterized by the very spiny marginals (two or three primary superomarginal spines, and proximally four or five, distally two or three, inferomarginal spines, both sets with accessory spinules); primary abactinal plates with a prominent denticulate spine, surrounded by a single series of much smaller spinelets; papular areas slightly two-lobed on ray, and extending to seventh superomarginal (one-seventh length of ray); furrow spines proximally two, long; distally three, shorter; subambulacral spines two, unequal, much longer than furrow spines; mouth plates with five or six marginal spines graduated in length from long inner tooth to a short outer spinelet; on actinal surface of mouth plates, five rather long spines in an angular series: dorsal muscle bands stout. Rays five; R = 158 mm.; r = 17 mm.; R = 8.3 r. Breadth of ray at base, 21 mm.

Description.—Abactinal plates stellate on papular area; lobes of primary plates five to eight; secondary plates with two or three lobes or none; beyond papular area plates are roundish or irregular, closely placed. Abactinal surface has much the appearance of that of *Luidiaster dawsoni*, but the primary spines are rather more numerous. These spines have strongly denticulate sides and each is mounted on a low tabulum and surrounded by a single circle of ten to fifteen short, sharp spinelets; secondary plates with one to four or five very inconspicuous spinelets. The primary spines are much shorter than in *Nearchaster aciculosus* (average 4 or 5 mm.). Beyond the middle of ray, spines are lacking and plates are covered with a uniform nap of minute granuliform spinelets, three or four to a plate. Abactinal pedicellariæ are very few and small, with four or five spinelets. Papulæ distributed all over disk and to seventh superomarginal, or about one-half length of ray; area distally slightly two-lobed.

Marginal plates not so evidently alternate as in *Nearchaster aciculosus*, but they are irregular in this respect. On some parts of ray they appear to be nearly opposite, while near by they alternate. Armature similar to that of *Nearchaster aciculosus*. Superomarginal spines two or three, surrounded by five to eight very slender and shorter accessory spinules. Numerous well-spaced, small, sharp spinelets are scattered over plate, mostly near the larger spines. Inferomarginals with proximally four or five spines; farther along ray, two or three. Accessory spinules prominent. There are five odd interradial marginals in both series, scarcely if any larger than adjacent plates although placed on a slightly higher level. Each bears two unequal or subequal spines, not quite so long as the adjacent superomarginal spines. A very few pectinate pedicellariæ, with ten or twelve short, blunt, slender papillæ, occur irregularly on three rays between the first and second or second and third inferomarginals, and three of the actinal interradial areas have one or two similar pedicellariæ. The actinal intermediate plates are very few (five to seven, and fifth adambulacral abuts against second inferomarginal), and are naked except for one to three prominent spines or spinules on each plate.

Adambulacral plates, with proximally one, two, and, distally, three unequal tapering furrow spinules, and on the actinal surface, two much longer, slender blunt spines about two and one-third or two and one-half times width of plate. That nearest margin is slenderer and slightly shorter and often stands at the aboral inner corner of plate, fairly on margin.

Mouth plates with a less extensive furrow margin than species of *Nearchaster;* furrow spinules five or six graduated from a long inner tooth to a very short outer spinelet. About five tapering sharp spines stand on the surface in an angular series.

Madreporic body fairly large convex situated its own diameter from margin and surrounded by four prominent spines. Striæ fine, radiating from center.

Color in life, above pinkish buff, grayish at base of ray on papular area; actinal surface, Naples yellow; tube feet, pinkish.

Dorsal muscle bands much stouter and broader than in *Nearchaster,* and more as in *L. dawsoni,* but not so thick as in that form. After the proximal ninth of ray the muscle becomes evident and runs parallel with the margin, being about 1.5 mm. wide. On the outer third of ray it joins its fellow and the entire width of the narrow dorsal integument is covered with muscle. In *N. aciculosus* the bands are thin enough to be translucent. This muscle is not attached to a proximal ambulacral ossicle, as in *L. dawsoni.*

Type.—Cat. No. 27802, U.S.N.M.

Type-locality.—*Albatross* station 4530, Monterey Bay, California, 958 to 755 fathoms, very soft mud, one specimen, *Albatross,* 1904.

Distribution.—Known only from type-locality.

Genus BENTHOPECTEN Verrill.

Benthopecten VERRILL, Amer. Journ. Sci. and Arts, vol. 28, September, 1884, p. 218 (footnote). Type, *B. spinosus* Verrill.

Pararchaster SLADEN, Narr. *Challenger* Exp., vol. 1, 1885, p. 610, fig. 204. Type, *P. pedicifer* Sladen; figure.

Diagnosis.—Benthopectinidæ with odd interradial marginal plates and rather flat immersed abactinal plates without definite arrangement and bearing single spines or groups; usually enlarged spines on disk; no paxillæ; papulæ confined to disk and base of ray, exceptionally extending to middle of ray. Rays very long, tapering, and flexible; disk small. Marginal plates suboval or triangular, elongate in the direction of ray, and confined strictly to margin, the two series not exactly opposite; each plate with a prominent boss. Superomarginal plates with usually one long cylindrical tapering spine, and sometimes a companion; inferomarginal plates with one or more similar spines (in one species clavate); general surface of plates of both series naked, or only with minute isolated spiniferous thornlets. Odd superomarginal usually with a very prominent spine. Actinal interradial areas with very few intermediate (ventral) plates. Armature of adambulacral plates consisting of a semicircular furrow series of small uniform spines, radiating fan-like, and one or more larger actinal spines. The furrow series are typically separated from each other by a considerable interval. Pectinate pedicellariæ may be present on any or all of the following regions: Abactinal plates, inferomarginal plates, actinal interradial areas. Superambulacral plates always absent; tube feet with sucking disks. Intestinal cœcum saccular, four-parted.

Remarks.—Ludwig in his recent paper on the Notomyota recognizes *Pararchaster* (type, *P. pedicifer*) for those species which have several spinelets on each abactinal plate, reserving for *Benthopecten* the forms which have one spine or spinelet to a plate. His genus *Pararchaster* corresponds to the second section [B] of Sladen's key (*Challenger* Asteroidea, p. 5), less *armatus.*

Such a division of *Benthopecten* into two genera, or even subgenera, would be useful, but in practice is difficult, in the absence of other correlative characters. At the start we find that *Benthopecten* in the restricted sense has three species, *incertus, cognatus,* and *simplex* with certain plates bearing two or three spinelets.

Among the following species *claviger* would undoubtedly fall in *Pararchaster. Mutabilis* has generally single spinelets on the rays, but the large spines of the disk are frequently surrounded by a circle of upward to ten or eleven short spinelets, while other plates have one to three or four short stubby spinelets, in no wise different from those present on typical "*Pararchaster.*" But *mutabilis,* while presenting several points of difference, greatly resembles *Benthopecten spinosus,* the type of the genus. One would not consider placing the two species in separate genera. *Benthopecten acanthonotus* is difficult to classify, if two groups are recognized. It would seem to belong with *Benthopecten* restricted, but in the type-specimen I find numerous plates with two and three spinelets. Another specimen, doubtfully referred to this species, and which, if not *acanthonotus,* is very closely related, has five or six spinelets surrounding the enlarged spines of the disk. The type also has two or three small spinelets next to some of the enlarged spines. The type of *Pararchaster* is not so well differentiated from *Benthopecten* as some other species included in the genus by Ludwig.

I have maintained *Benthopecten* in the extended sense in which Verrill and I have already used it, and coextensive with *Pararchaster* Sladen, Perrier, Kœhler, and Ludwig previous to 1910. I do this because I find great practical difficulties in using the two generic names. I believe that it will be possible to split up *Benthopecten,* but I doubt if *Pararchaster* can be used as a name, because its type is too closely allied to *B. spinosus.*

Some hint of a possible division was afforded by the distribution of papulæ in *B. acanthonotus.* Here the papulæ extend far along the ray or are confined to the basal portion, depending apparently upon the age of the individual. The character is, however, too variable to be of use as a generic feature in this group, and I think the same is true of the number of spines on the abactinal plates, unless accompanied by some more conservative structural feature as yet undetermined.

KEY TO THE SPECIES OF BENTHOPECTEN HEREIN DESCRIBED.

a^1. Inferomarginal plates with pectinate pedicellariæ at base of ray only; or if occurring beyond middle of ray, actinal spinelets clavate (b^2). Odd interradial marginal plates normally present in all interradii. Actinal interradial areas small.
  b^1. Abactinal plates of ray with only one slender central spinule; abactinal pedicellariæ numerous on ray extending nearly to tip; actinal and inferomarginal spines of proximal part of ray not clavate; papulæ often extending beyond eighth superomarginal..........*acanthonotus*, p. 144.
  b^2. Abactinal plates of ray proximally with one spinule and several minute spinelets, beyond papular area with one to several minute spinelets; proximally the actinal and inferomarginal spines clavate; abactinal pedicellariæ usually confined to disk and base of rays; papulæ extending to fifth superomarginal..*claviger*, p. 150.
a^2. A majority of interradii usually without odd interradials, and inferomarginals with pedicellariæ nearly to tip of ray. A few prominent spines in center of disk, the others short and stubby, robust. Interradial areas larger..*mutabilis*, p. 147.

BENTHOPECTEN ACANTHONOTUS Fisher.

Pl. 22, figs. 2, 3; pl. 23, figs. 1, 2; pl. 28, fig. 3; pl. 54, fig. 5; pl. 56, fig. 2.

Benthopecten acanthonotus Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 299; Zool. Anz., vol. 35, March 29, 1910, p. 547.

Diagnosis.—Rays five. R = 164 mm., r = 14 mm., R = 11.7 r. Breadth of ray at base, 16 mm. (from station 2919). Rays narrow, depressed, long, and very gradually tapering to the attenuate extremity. Abactinal surface with lobed plates (on papular areas) bearing a single spinule, and also one to several very small spinelets. Pectinate pedicellariæ numerous on abactinal surface, and extending far along ray. Papular areas extensive; papulæ extending as far as seventh to twentieth superomarginal. Superomarginals with one spine; inferomarginals with two; adambulacrals with four to seven furrow spinelets and two much longer actinals; mouth plates with four or five furrow and four or five actinal spines. Actinal interradial areas small with one to three pectinate pedicellariæ. Inferomarginal plates with pectinate pedicellariæ at base of ray only. Superambulacral plates absent, but each ambulacral with a fairly high thin dorsal ridge or carina, joined tightly to marginal plate at its outer end.

Description.—Abactinal surface beset with rather widely spaced very slender rugose or thorn-covered spinules; on ray one to a plate, but on disk usually accompanied by from one to six very small spinelets, sometimes forming a circle when numerous. Spinules are largest on disk, being there unequal, however, and ranging from about 1.5 mm. to 6 mm. in length; on rays they are about 1.5 mm. long. Primary abactinal plates, particularly the basals, have the longest spines. Abactinal pedicellariæ numerous, composed of two or three opposing series or combs of three to six converging sharp spinelets. The apparatus is usually circular in form and from 0.75 to 1.5 mm. in diameter, there being a total of nine to fifteen spinelets, except far along ray where the pedicellariæ are beginning to form, and have only four or five spinelets. Pedicellariæ rather numerous on disk and more so on ray, where they are found usually on either side of the median radial area, and extend nearly to tip of arm. (See figure.)

Abactinal plates when examined from inner surface are seen to be irregularly lobed. In the type the plates are more delicate than in the other specimen. Plates may touch by the lobes or may be entirely separated. Beyond papular area plates lose the lobes, are irregular to quadrate elliptical in form, and on the outer part of ray are quite widely spaced. Papulæ numerous, one to a pore, and distributed all over disk (except narrow interradial line), and basal part of ray, but from fourth to fifth superomarginal to far along ray (varying from eighth or ninth to twentieth superomarginal) the papulæ are confined to either side of the medioradial area. Naturally the papulæ dwindle as they recede from disk. Thus the extent of the papular area on rays is variable. The papulæ extend farther along ray than in any other species of the genus.

Marginal plates thin, confined to side wall of ray, elongate elliptical in form, the inferior margin of the superomarginal being slightly oblique to long axis of ray. The plates of the two series are nearly opposite. Superomarginals fifty-four, each bearing on a prominence of the center a long slender tapering spine, that of third and fourth plate being longest (8 mm.) except for the odd interradial spine. Two or three capillary spinelets stand on the adoral half of the plate and one or two near the spine. Inferomarginals each with usually two spines in a vertical row, the lower, half or two-thirds the length of the upper; the latter about the length of superomarginal spines. A few scattered capillary spinelets stand on the general surface. Dorsal interradial marginal bears a 10 to 12 mm. spine and several spinelets. A large and two small specimens from station 2919 have no odd plate in either series in one interradius. The odd inferomarginal is armed with one or two shorter spines. Between the odd inferomarginal and the first paired plate, between the first and second, and sometimes the second and third or third and fourth also, is a prominent pedicellaria with six to ten tapering spines in each comb. The longest of these spines equals one-third or slightly more of the length of the comb. The apparatus does not usually occupy the whole height of the plate. One or two additional pedicellariæ occasionally occur in the neighborhood of the seventh to tenth plates, but beyond that inferomarginal pedicellariæ are absent.

Adambulacral plates with a semicircular prominence into furrow. Armature consists of (1) a furrow comb of four or five slightly curved, slender, blunt spinelets, three of which are about equal, the extra ones (laterals) being shorter. One specimen (station 2919) has regularly six or seven furrow spinelets. There is a wide interval between successive combs. (2) On actinal surface of plate are two slender slightly tapering blunt spinules in a transverse series, sometimes the inner, sometimes the outer being the longer, the longest equaling one and one-half to two plates in length.

Mouth plates large, convex actinally. Armature (1) a furrow series of four or five spines which increase rapidly in size toward the inner angle, where the innermost of each plate form two prominent teeth, much heavier than the others. (2) On the actinal surface is a linear series of four or five rather long, slender, blunt spines, decreasing in length toward outer end of plate; the inner two stand in a series parallel with furrow, the rest parallel to suture.

Actinal interradial areas very small. In the type the second adambulacral plate is in contact with the first paired inferomarginal; this is, however, extreme. The two other large specimens have either the fourth or fifth adambulacral touching the second paired inferomarginal. There may be as many as twenty intermediate plates in each angle, although the type has only two or three. One to four pectinate pedicellariæ with five to seven spinelets in each comb occur on each interradial area of the example from station 2919. The type has only one pedicellaria to an area. The plates have besides one or two spinules.

Madreporic body convex, prominent, circular, with coarse irregular centrifugal striations. It is situated one-half to more than its own diameter from the odd superomarginal plate.

Variations.—Only three large specimens are available, the type which lacks the distal portion of all the rays, and two examples from station 2919. The latter (one with one entire ray) have a considerably larger disk and larger actinal interradial areas than the type as well as more extensive papular areas on the ray. The rays are also wider at base. But a third specimen from the same station has a disk relatively the same size as type, and papular areas which extend only to the fifth superomarginal. The type is possibly a more immature individual, which would account for the difference in development of disk, actinal intermediate plates, and papular areas (to eighth superomarginal). The absence in one interradius of the interradial unpaired marginal (of both series) is of interest. One superomarginal in this interradius is slightly larger than its neighbor and corresponds to the odd plate. In *Benthopecten mutabilis* the odd plate is frequently absent; and indeed in the type of the genus, *B. spinosus* it is also sometimes absent, as a full-grown specimen from station 2711, off Cape May, has paired plates in two interradii. Variations in adambulacral spines, and in occurrence of pedicellariæ have already been alluded to in the description. A young specimen with R about 50 mm. lacks pedicellariæ entirely. There are six prominent disk spines, of which the central is largest. The central slender spinule of the other abactinal plates is characteristic, differing markedly from the minute spinelets of *claviger* or the stubby granuliform tubercles of *mutabilis*. In these young the rays have a hirsute appearance. Another specimen, but a trifle larger, has inferomarginal but no abactinal pedicellariæ. It is interesting to note that a very small example (R = 11 mm.) has two inferomarginal pedicellariæ, with twice three or twice four spinelets, in each interradius; but there are no prominent abactinal spines and no abactinal pedicellariæ. There are five prominent interradial superomarginals and spines. There is but one furrow spine. An example with R = 70 mm. has abundant abactinal and the usual number of inferomarginal pedicellariæ.

Type.—Cat. No. 22330, U.S.N.M.

Type-locality.—Off San Diego, California (longitude of Point Conception), 1,059 fathoms, mud.

Distribution.—Southern California; 984 fathoms to 1,059 fathoms.

Specimens examined.—Seven, the type, and six from station 2919, off Cortes Bank (west of San Diego), in same general locality as that of type, 984 fathoms, gray mud.

Remarks.—This is a variable species, especially in the extent of the papular areas, size of disk, and number of abactinal accessory spinelets. The type is probably not a fully grown example, and therefore has less extended papular areas on rays, smaller disk, and fewer accessory abactinal spinelets than two examples from station 2919. A third and smaller specimen from station 2919, has a disk relatively as small as that of type and even less extensive papular areas. The slight differences in abactinal spinulation are not sufficient to warrant specific separation.

In his key, Ludwig (1910) places *B. pectinifer* in the second section and *acanthonotus* in the first. *Acanthonotus* belongs in the second section, however, as there is no sharp differentiation between disk and ray in the dorsal spinulation, except with respect to the central, and primary basal spines. In this second section, *acanthonotus* differs from *huddlestoni* in having two inferomarginal spines, four or five ambulacral furrow spines, four or five oral spines, two subambulacral spines, and in lacking inferomarginal pedicellariæ throughout the ray. From *pectinifer*, *acanthonotus* differs in the rather stouter abactinal spines, somewhat smaller marginal pedicellariæ, and single inferomarginal spine; *pectinifer* differs slightly in having six to eight oral spines, and five or six furrow spines (instead of four or five) and two or three subambulacral spines (instead of two). The two species are very close; it is possible they are varieties of one wide ranging form, since *acanthonotus* shows considerable individual variation.

BENTHOPECTEN MUTABILIS Fisher.

Pl. 22, fig. 1; pl. 23, fig. 3; pl. 54, figs. 6, 6*a*.

Benthopecten mutabilis FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 548.

Diagnosis.—In general appearance similar to *B. spinosus* Verrill, but usually lacking some of the odd interradial marginal plates (always in one or the other series, as a rule in both); abactinal, actinal intermediate, and inferomarginal pedicellariæ, the latter series extending to tip of ray, the first extending far along ray, as a rule; (pedicellariæ lacking in *B. spinosus*). Abactinal surface with several large spines near center of disk, each usually with several small spinelets surrounding; other plates of disk with one to three or four very short stubby spinelets, and plates or ray with typically one such spinelet. Superomarginal with one, inferomarginal with two unequal spines. Adambulacrals with five or six subequal furrow spinelets and two actinal spinelets. R = 100 mm.; r = 15 mm.; R = 6.6 r. Breadth of ray at base, 17 mm. Interbrachial arcs wide and rounded and beyond papular region the rays slope very gradually to an attenuate extremity; from interradial line to about fifth superomarginal they slope abruptly making the wide interbrachial angles.

Description.—There are no prominent abactinal spines except near center of disk within the radius of the madreporic body. These spines are about 6 or 7 mm. long, tapering and acicular, and are borne on the primary plates: central, radials, basals, and probably infrabasals also in some cases. The other plates of disk bear one to three or four, less commonly five to six or seven, very short stubby spinelets and several usually occur around the base of the central spines. On the rays each plate has usually one central spinelet, but in one specimen there are regularly two, three, or even four, one being larger than the others. This is aberrant, however. These spinelets are all under 1 mm. in length, and most of them 0.5 mm. or less. The larger ones occur on the papular areas and are rudimentary central spinules. There is great variation in their number, but they are never numerous and never extend very far upon ray, being about 1 mm. long.

In some specimens abactinal pectinate pedicellariæ are about as numerous on disk and rays as in *acanthonotus*, but on one example they are comparatively scarce. Each comb consists of three to six short robust, blunt, spinelets, typically much stouter and broader than in *acanthonotus*. While most of the pedicellariæ consist of two combs there are some with three, in which case each comb has few spinelets. Far along ray the spinelets are very short and inconspicuous.

Abactinal plates of papular areas much less distinctly lobed than in *acanthonotus*. The larger plates are roundish with a few irregular slight projections. The intermediate small plates are roundish on disk, but on ray more irregular with two or three lobes, or none. On papular areas the plates generally touch, but on ray they become quite widely separated, especially on the median radial area. Papulæ confined to base of ray and disk, but are absent from the center of disk and a narrow interradial line. They do not extend as far upon ray as its width at base.

Marginal plates thin, confined to side wall of ray, each superomarginal with one stout tapering sharp spine, the inferomarginals on proximal part of ray with two, on distal with one such spine. Of the two the lower is much smaller than the other, which is about the same size as the corresponding superomarginal spine. The general surface of plates is naked, but one to several additional small spinelets occur on the plates of both series. Superomarginals, in type, forty-one. In the type there is but one odd interradial superomarginal, the other four interradii having paired superomarginals. The same specimen has three odd inferomarginals. This character is very variable. One specimen has no odd superomarginal, and two odd inferomarginals; another (otherwise not very typical) has five odd superomarginals and three or four odd inferomarginals; another has three odd superomarginals; another, one. The interradial superomarginal (paired or unpaired) usually bears a stout spine and is raised higher than the rest, but when paired the spine is frequently weak.

Inferomarginal plates with a pedicellaria on the vertical suture, these occurring all along ray with now and then a suture lacking the apparatus. Proximally each comb has eight or nine short, stubby, basally webbed papillæ, which soon become five or six, and on the outer part of ray about three.

Adambulacral plates with five or six blunt furrow spinelets and two much larger, tapering actinal spines in a transverse series. The furrow spinelets are short and the central only slightly longer than the laterals.

Mouth plates with five or six marginal spinelets, of which all but the much enlarged inner tooth are similar to though a trifle longer than the corresponding adambulacral spinelet On the actinal surface is a linear series of four or five longer spinules, not markedly different from those of *B. spinosus*.

Actinal interradial areas fairly extensive for this genus, with one to four, or without pectinate pedicellariæ. Sometimes they are incomplete (with one comb). Each comb has three to seven blunt basally webbed papillæ or spinelets. The number and arrangement of pedicellariæ is very irregular. Intermediate plates extend to about the fourth inferomarginal and each has one to three unequal stumpy spinules.

Madreporic body circular, situated remote from margin, so that *outer* edge is about middle of minor radius, or even adcentral to the middle point. In *B. spinosus* the madreporic body is nearer margin, so that its *inner* or adcentral edge is at the middle of r, or outside of middle.

Anatomical notes.—Superambulacral plates absent, but their place is taken by a thin dorsal carina of the ambulacral ossicles. The outer end of this is fastened to the superomarginal plate, while the main axis of the ossicle abuts against the inferomarginal. Gonad confined to disk, opening close to margin and interradial line; interradial septum membranous. Intestinal cœcum with four obtuse divisions; no real distinction between dorsal and ventral stomachs. Polian vesicle in each interradius except that of madreporic body. Two ampullæ; tube feet with small sucking disks.

Variations.—Individual variations have already been noted in the description. The most important of these is the variable number of odd interradial marginal plates.

Young.—A young specimen, R=30 mm., r=5 mm., lacks pedicellariæ and bears a striking resemblance to young *B. spinosus* except that there are only two unpaired interradial superomarginals. The characteristic abactinal spines of the disk are present and very conspicuous, while the other abactinal plates bear a single tiny spinelet each. A similar-sized individual of *B. spinosus* has only one or two disk spines and very prominent unpaired interradials.

Type.—Cat. No. 27803, U.S.N.M.

Type-locality.—*Albatross* station 2859, off Prince of Wales Island, British Columbia, 1,569 fathoms, gray ooze; eight specimens.

Distribution.—Known only from type-locality.

Remarks.—As already indicated, this species in general appearance most nearly resembles *B. spinosus* Verrill, but differs in having an abundance of abactinal and inferomarginal pedicellariæ, only one large inferomarginal spine with a shorter companion below it, shorter rays, as well as a broader disk, and in lacking one or more odd interradial superomarginals. From *B. pedicifer* (Sladen) it differs in having much shorter rays, larger disk, less numerous furrow spinelets, one less actinal adambulacral spine, more prominent abactinal disk spines, and also in respect to the variable odd interradials. *B. pedicifer* was taken by the *Challenger* south of the Cape of Good Hope and west of the Crozet Islands. Sladen notes the same variation in abactinal spinelets in *pedicifer* that occurs in *mutabilis*. From *B. acanthonotus, mutabilis* differs in respect to the abactinal spinulation, the former having a delicate spinule on each plate of ray, not one or more very insignificant spinelets; in the restriction in *acanthonotus* of the inferomarginal pedicellariæ to the base of ray. All pedicellariæ in *mutabilis* have shorter and thicker often webbed spinelets, and the actinal interradial regions are larger and fuller. The difference in interradial plates also holds, and the madreporic body is nearer margin in *acanthonotus*. From *B. antarcticus* Sladen, *mutabilis* differs in having only one superomarginal spine, and two subambulacral spines, and from *semisquamatus* in having a much broader disk, shorter and proximally broader rays, shorter spinelets on rays, numerous inferomarginal pedicellariæ, and a variable number of odd interradial plates.

BENTHOPECTEN CLAVIGER Fisher.

Pl. 22, fig. 4; pl. 54, fig. 4; pl. 56, figs. 1, 1*a*–*b*.

Benthopecten claviger FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 548.

Diagnosis.—Rays five. R = 110 mm.; r = 12 mm.; R = 9.1 r. Breadth of ray at base, 14 mm. Disk small, rays long and evenly tapering; interradial angle abrupt. Abactinal surface of disk with numerous conspicuous thorny-surfaced spines which extend upon rays for a short distance, these surrounded at base by eight to fifteen or even more very small thorny spinelets; numerous intermediate plates with one to five tiny spinelets; on ray plates with one to five similar spinelets forming a fine nap. Interradial odd superomarginal very prominent. Abactinal pectinate pedicellariæ present but usually variable in number. Inferomarginal and actinal adambulacral spines of proximal part of ray club-shaped, the former two, the latter two (sometimes three) in number. Furrow spines four to six, slightly curved. Pectinate pedicellariæ between proximal inferomarginals, rarely farther along ray. The most characteristic features of the species are the clavate actinal and inferomarginal spines, the prominent thorny disk spines and the extremely delicate abactinal spinelets which often are exceedingly small. Tube feet with small sucking disks.

Description.—Disk and basal part of rays (papular areas) covered with numerous spaced, tapering, blunt, superficially thorny spines, which decrease in size from center of disk outward, ranging from 5.5 mm. to 1.25 mm. in length. These stand on an eminence of plate which is surrounded by eight to fifteen or even more very small, delicate, microscopically thorny spinules or spinelets, ranging from about 0.2 to 0.4 mm. in length. Numerous small intermediate plates bear one to five very tiny spinelets (about 0.2 mm. in length) which cannot be seen without a glass. Plates of ray bear one to five minute sharp, slender spinelets about 0.3 mm. long at base of ray and 0.1 mm. toward tip. These groups of spinelets (often standing on plate in a series) form a sort of fine uniform nap on the abactinal surface of ray. Some of the major spines are slightly club-shaped. Abactinal pectinate pedicellariæ are variable in number. Typically they are absent or very few on rays, and few on disk. One specimen from the type-locality has numerous pedicellariæ along rays, as well as scattered over the disk. Each apparatus is subcircular or elliptical and has two to four robust, but short, papillæ in each comb. These blunt comb-spinelets are many times thicker, but only slightly longer than the spinelets of abactinal plates. Each apparatus is from 0.5 to 1 mm. in diameter.

Papulæ extend along ray to about fifth or sixth superomarginal. There is a small area in center of disk and along each interradial line from which they are absent. On the papular areas the abactinal plates vary greatly in shape with age. In adults they are strongly lobed, the larger with six or seven lobes. The smaller secondary plates have two or three lobes and all plates touch and usually join by these. Outside the papular areas the abactinal plates are roundish, and far along ray are spaced in the median radial areas. The "primary apical" plates are prominent in small and medium-sized specimens.

Marginal plates in form not different from the two preceding species. Plates of the two series are obliquely opposite, but not alternate, the lower plate being slightly farther distad than the upper. The intervening suture is oblique. Superomarginals, about forty in number, with a prominent boss on the upper rounded margin bearing a single, tapering, bluntly pointed, thorny (almost hispid) surfaced spine, proximally 5 or 6 mm. long; exceptionally two are present on one or two plates; seven or eight small thorny spinelets are irregularly distributed over the surface of the otherwise naked plates. The odd interradial superomarginal is prominent, is elevated half its height above the level of the other superomarginals, and bears a single upright spine 7 mm. long.

Inferomarginals bear two spines (or sometimes only one) similar, and the longer subequal, to those of upper series, except at base of ray where both spines are typically club-shaped, with a broader tip than base. Farther along ray, however, the spines taper. The lower of the two is the shorter. Ten or twelve spinelets are scattered on surface of plate. The unpaired inferomarginal bears one or two short club-shaped spines with sometimes one or two accessory club-shaped spinules. Typically the proximal first, second, and sometimes third, or first and third, or first only, vertical inferomarginal sutures have a pectinate pedicellaria with three to six robust sharp converging spinelets to each comb. The aberrant specimen noted above as having numerous pedicellariæ on the abactinal surface of rays has the inter-inferomarginal pedicellariæ extending far along rays.

Adambulacral plates wider than long; the furrow series of consecutive plates well spaced. Armature (1) a furrow series of four to six subequal slightly curved spinelets, the median two or three about as long as plate, or the laterals markedly shorter. (2) On the actinal surface are two strongly club-shaped spines in a transverse series, with sometimes proximally a third much smaller one at outer end of the line. Far along ray the spines are not so obviously club-shaped, or they may taper a trifle, but are blunt and stout at tip. One or two additional spinelets stand on the adoral side of the plate. The form of the proximal actinal adambulacral spines seems to be characteristic and holds in specimens from widely separated localities.

Mouth plates with marginal graduated series of five or six spines, the inner and sometimes the next much enlarged; parallel to median suture is a linear series of about six actinal club-shaped spines, which become slenderer as they proceed outward.

Actinal interradial areas small; much smaller than in the *B. mutabilis;* six to eight plates in each area, these extending to the second inferomarginal. Each plate has a few unequal clavate spinelets, one usually larger then the rest. In the aberrant specimen already referred to, each area has one to five pectinate pedicellariæ with three or four pointed spinelets in each comb. Another specimen has one or two rudimentary pedicellariæ (the spinelets being very short) in each area. The type has none.

Madreporic body within its own diameter from the interradial plate, and surrounded by about five prominent spiniferous plates. The adcentral of these is the primary basal.

Anatomical notes.—No superambulacral plates; the ambulacral ossicles produced dorsally into a thin carina as in other species of genus (except at base of ray).

Young.—From station 3601 are a number of young and middle-sized specimens. These exhibit most of the characteristics of the adult, especially the club-shaped inferomarginal and actinal adambulacral spines, pedicellariæ, and minute abactinal spinelets. The spine-bearing plates of disk are very prominent, but the spines themselves are not so numerous nor so prominent as in the adult. The thorny surface of the spines is quite apparent. Far along ray the abactinal plates have only one or two minute spinelets. In such a specimen (R=43 mm.) there is a considerable area at center of disk in which no papulæ occur and the actinal interradial areas are relatively as large as the types.

Type.—Cat. No. 27804, U.S.N.M.

Type-locality.—*Albatross* station 3788, off Cape Blanco, Oregon, 1,064 fathoms, green mud, three specimens.

Distribution.—Southern Bering Sea to Oregon and from 987 to 1,064 fathoms, green mud or ooze.

Specimens examined.—Besides three from type-locality, thirteen from three stations as follows: 3307, southern Bering Sea (lat. 53° 55′ N.; long. 170° 50′ W.), 1,033 fathoms, green ooze, two specimens; 3601, Bering Sea, midway between the above and St. George Island, 1,044 fathoms, green mud, fine sand, ten specimens, medium sized and small; 3607, north of Unalaska, 987 fathoms, green mud, one specimen.

Remarks.—This species can be distinguished from the two others here described by the characteristic clavate inferomarginal and actinal adambulacral spines of the proximal part of the ray, and by the prominent disk spines in connection with very delicate spinelets—several to a plate. The only species described by Ludwig from the Panama-Galapagos region with which this needs comparison is *B. spinuliger*, which differs in lacking the prominent spines of disk, in having numerous (thirteen to sixteen) marginal mouth spinelets, and in lacking the characteristically formed actinal spines.

In Ludwig's key to *Pararchaster* (restricted) this species falls in the first section, next to *pedicifer*. It differs from this in the *clavate* actinal and marginal spines, as well as in the following features: more prominent and more numerous abactinal spines, in having three subambulacrals on proximal plates only, nineteen proximal adambulacrals to ten inferomarginals, as well as in proportion and minor details of armature. The two forms are not at all nearly related.

Family ODONTASTERIDÆ Verrill, 1899.

Gnathasterinæ (part) PERRIER, Expéd. sci. du *Travailleur* et du *Talisman*, 1894, pp. 244, 251.
Odontasteridæ VERRILL, Trans. Conn. Acad., vol. 10, 1899, p. 201.—FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 302.

Form similar to that of the more paxillose Goniasteridæ, being either pentagonal or broadly stellate. A single recurved, more or less hyaline median spine to each pair of mouth plates, or two such spines, side by side; in the latter case one of these spines arises from near the apex of each mouth plate. An odd interradial marginal plate in both series. No superambulacral ossicles. Tube feet with sucking disks as in Goniasteridæ. Marginal plates well developed, either decreasing regularly in size distally, or at first increasing (as in *Pentagonaster* Gray) so that the rays are dilated. Abactinal, actinal intermediate and adambulacral plates as in *Odontaster*.

This family includes three well marked genera, two of which are extra limital.

KEY TO THE KNOWN GENERA OF ODONTASTERIDÆ.

a^1. A recurved hyaline spine on each mouth plate, two side by side at each mouth angle.
  b^1. Marginals decreasing regularly in size from base to extremity of rays...... *Asterodon* [a] Perrier.
  b^2. Marginals at first increasing in size; rays dilated...................... *Diplodontias* [b] Fisher.
a^2. A recurved hyaline spine common to the two mouth plates, therefore one at each mouth angle. *Odontaster* Verrill, p. 154.

Remarks.—Sladen placed his genus *Gnathaster* in the Pentagonasteridæ next to *Nymphaster*, while Perrier relegated *Asterodon*, which when described included both *Asterodon* and *Gnathaster* (or *Odontaster* as now known) in the Archasteridæ. Bell in 1893, in his revision of *Odontaster*, followed Perrier. In 1894 Perrier placed *Asterodon*, *Goniodon*, and *Gnathaster* in the subfamily Gnathasterinæ of the Archasteridæ. In 1899, when Verrill dismembered the Archasteridæ, he created the family Odontasteridæ and placed the new group next to the Goniasteridæ.

The positive characters of the genera included in this family fully warrant, in my opinion, the step taken by Verrill, and I venture to suggest that the family is nearer the Goniasteridæ than to any group formerly included in the Archasteridæ (which is now restricted to *Archaster*). The fact that all the species described previous to Sladen's report were originally placed in goniasterid genera [c] further bears out the unanimity of opinion concerning the structure of the forms. Nevertheless Perrier and Bell believed the group to be nearer the Archasteridæ, while freely admitting its intermediate character. The goniasterid similarities are to be found in the structure of the abactinal, marginal, and actinal intermediate plates, the form of the adambulacral plates, the absence of superambulacral ossicles, the form of the tube feet with their well developed sucking soles or disks. The adambulacral armature is not unlike that of *Gephyreaster* (described in this report), which is an annectant genus near *Pseudarchaster* and *Mimaster*. The abactinal parapaxillæ, which are the sole "Archasterid" reminders, are not true paxillæ and are similar in structure to those of *Mediaster*, *Nymphaster*, and allied genera, which no one would think of placing in the old Archasteridæ. Professor Verrill's course has in a measure cut the Gordian knot, and the genera are far better in a separate family than in the Goniasteridæ.

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[a] Échinodermes de la mission scientifique du Cap Horn. I. Stellérides. Mission scientifique Cap Horn. Zoologie, vol. 6, Paris, 1891, p. 129.

[b] *Goniodon* Perrier (Expéd. sci. du *Travailleur* et du *Talisman*, 1894, p. 244); type, *Pentagonaster dilatatus* Perrier. As this name is antedated, and therefore invalidated, by *Goniodon* C. L. Herrick, Denison Univ. Scientific Laboratories, Bull. 3 (April), 1888, p. 4 (type, *G. ohioensis*, a mollusk), I renamed the group *Diplodontias* in 1908 (Smiths. Misc. Coll., vol. 52, p. 89).

[c] These species were:
Goniodiscus singularis (now *Asterodon singularis*).
Pentagonaster dilatatus (now *Diplodontias dilatatus*).
Astrogonium miliaris (now *Odontaster miliaris*).
Astrogonium meridionale (now *Odontaster meridionalis*).
Calliderma grayi (now *Odontaster grayi*).

Genus ODONTASTER Verrill.

Odontaster Verrill, Amer. Journ. Sci., vol. 20, 1880, p. 402. Type *O. hispidus* Verrill; Proc. U. S. Nat. Mus., vol. 17, 1894, p. 262; Amer. Journ. Sci., vol. 49, 1895, p. 136; Trans. Conn. Acad., vol. 10, 1899, p. 205 (restricted).—Bell (part), Proc. Zool. Soc. Lond., 1893, pp. 259–262.—Ludwig, Zeitschr. Wiss. Zool., 1905, p. 42.

Gnathaster Sladen (part), *Challenger* Asteroidea, 1889, p. 285.—Perrier, Expéd. sci. du *Travailleur* et du *Talisman*, 1894, p. 244.—Verrill, Trans. Conn. Acad., vol. 10, 1899, p. 204 (restricted to *meridionalis*, *penicillatus*, and *grayi*).

Acodontaster Verrill, Trans. Conn. Acad., vol. 10, 1899, p. 204 (for *Gnathaster elongatus* Sladen and *Astrogonium miliare* Gray).

Diagnosis.—One odd, median, hyaline, more or less movable recurved spine on each pair of prominent mouth plates, which may be close together or separated by an open fusiform space covered with membrane. An odd triangular interradial plate in both marginal series. Marginal plates usually prominent, decreasing in size distally, and covered with granules or short spinelets. Abactinal plates more or less paxilliform, often stellate, arranged in series parallel with the radial, also in oblique transverse rows on rays; papulæ single, in the angles around radial paxillæ, and sometimes in center of disk. Adambulacral plates small, wider than long, with straight furrow margin as in Goniasteridæ. Furrow spinelets two to five, and several longitudinal rows of two or three on the surface of plate. Actinal intermediate areas broad, the plates in regular series parallel with furrow, and covered with granuliform spinelets or well-developed spinelets. Simple pedicellariæ sometimes present. Superambulacral plates absent. Tube feet with well-developed sucking disk.

Remarks.—The genus as here defined includes the restricted genera *Odontaster*, *Gnathaster*, and *Acodontaster* recognized by Verrill in 1899. It does not include *Asterodon* Perrier, nor *Diplodontias* Fisher (*Goniodon* Perrier).

ODONTASTER CRASSUS Fisher.

Pl. 29, figs. 1–4; pl. 56, fig. 6.

Odontaster crassus Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 302

Diagnosis.—Nearly related to *O. grayi* Bell. R = 21 mm.; r = 13 mm.; R = 1.5 r. Breadth of ray at base 15 mm. Form stellato-pentagonal with distinct rays, these short and blunt; disk large. Marginal plates massive, the superomarginals forming a raised broad border to abactinal area; eight to a ray, and covered with granuliform spinelets; odd interradial plate large; inferomarginals less tumid than superomarginals and granulation coarser. Abactinal plates paxilliform on papular areas and lobed, with fifteen to twenty-three spinelets on radial series. Papulæ restricted to a central and five radial areas. Adambulacral plates with eight or nine spinelets terete, tapering and bluntly pointed, arranged with two on furrow margin, and on actinal surface in about three longitudinal series, two spinelets to each. Mouth plates with a movable, recurved, conspicuous lanceolate spine common to the pair, and a marginal series of five to eight spinelets graduated from center of series toward either end. Actinal interradial areas large, with squarish plates in regular series parallel to furrow, each plate bearing a group of five to twelve radiating stout, short, pointed spinelets. Superambulacral plates absent. Tube feet with well-developed sucking disks. No pedicellariæ.

Description.—Abactinal plates paxilliform on papular areas (q. v.); elsewhere simply strongly convex or only slightly elevated and with flattish top. Plates are arranged in regular series parallel with the median radial which contains largest plates with the exception of the conspicuous primary basals and central plate. Plates are also in regular rows parallel to interradial line, but inside of the pentagon defined by the five basals the plates are not regularly arranged. Opposite first two marginals are five rows of paxillæ. Tabulum of paxilla is so formed that summit is narrower than base, the side sloping upward gradually. Tabulum on papular areas, surmounted by a radiating group of fifteen to twenty-three (on radial row) slender tapering spinelets which are longer than height of tabulum. The paxillæ decrease in size toward margin of area. Right in center of disk is a small isolated papular area with paxilliform plates. The central plate has twenty-seven spinelets. About two rows of plates along interradial line and one or two rows connecting the basal plates (thus forming a pentagon inclosing the central papular area) have shorter spinelets than the rest. The primary basal has thirty-five to forty spinelets or elongate granules.

There are five radial papular areas, separated by two or three rows of plates along each interradius, and a central area isolated by or inclosed within a pentagon the corners of which are the five basal plates. The sides of this pentagon are about three plates thick, although there is no regular arrangement of plates. Papulæ, six about each plate, extend nearly to tip of ray, and are absent from margin opposite first two or three marginals. Plates of papular areas slightly lobed, the lobes of adjacent plates fitting together end to end, but overlapping slightly upon radial series, and always in central papular area where the plates are smaller and more crowded. Elsewhere the plates are subcircular or very irregular, three to five sided. Here and there adjacent to papular areas are very small plates, probably large plates in course of development.

Marginal plates massive, the superomarginals forming a broad, raised, arched border to abactinal area; last two or three plates in contact medially, though the last pair of plates is usually separated by wedge-shaped terminal plate. In type, seventeen plates to side, or eight to ray; interradial slightly larger than others, subtriangular superomarginals transversely oblong, wider than high, tumid, covered with spaced granuliform spinelets, which are thimble-shaped on rounded margin of ray, and decrease in size and thickness toward inner edge of plate. A narrow bare channel between consecutive plates, and a longitudinal channel on side of ray, separating the two series.

Inferomarginals correspond in number and position to superomarginals, but are not so tumid. Granuliform spinulation is coarser than on superomarginals, and increases similarly in size toward outer edge where the granules are thimble-shaped or truncate cylindrical. The unpaired plate is not quite so large as that of dorsal series. Rather deep channels between plates. Terminal plate, cordate, convex, broad end distally; covered with short spinelets, two being thicker than the rest.

Adambulacral plates wider than long. They are short with a narrow transverse suture, the plates having a crowded appearance. Furrow margin straight, and plates generally oblong like some species of *Tosia* and *Pentagonaster*. Armature consists of two terete, tapering, bluntly pointed spinelets on the furrow margin, one slightly smaller than the other, the longest slightly shorter than width of plate. On actinal surface are six or seven similar but sometimes sharper spinelets which diminish in size as they recede from furrow, and are usually disposed in three more or less regular longitudinal series (or oblique longitudinal), two spinelets to each, and the spinelets unequal as in furrow series; spinelets of first and second series often slightly longer than furrow series, the outermost shorter, about the size of adjacent actinal intermediate spinelets. The spinelets form a fairly thick chevaux-de-frise all along the border of the very narrow ambulacral groove, resembling that of *Gephyreaster swifti*.

Mouth plates with a movable, recurved, conspicuous, lanceolate spine, which has an obtuse inner end or base and a sharp outer glassy tip; one to each pair of plates; this spine is rather broad actinally, not much compressed, and nearly as long as interradial dimension of plates. Each plate is a low isosceles triangle in shape, the base being toward interradial suture. Along the straight furrow margin are five to eight spinelets similar to but often smaller than adambulacral spinelets, and graduated in length from center toward either end of series, the inner being shorter than outer. On surface of plates five to eight spinelets form an irregular line at side of median spine.

This recurved median spine or "tooth," which forms the principal character, in addition to the unpaired marginal plates, of the family Odontasteridæ, is nothing more than the very much developed median or odd marginal spine such as is found in most species of *Pseudarchaster*, and in *Gephyreaster*. In growing it is bent backward over the surface of the mouth plates, and comes to lie wholly on the exposed surface of the pair, the marginal spinelets encroaching upon the inner angle of the combined plates.

Actinal intermediate areas large. The plates are square and arranged in regular series parallel to furrow, along which they extend three-fourths the length of R (to fifth inferomarginal). Plates bear a group of five to twelve radiating, stout, short, tapering pointed spinelets (on some specimens much longer on middle of plate), occasionally forming a fairly ornate rosette.

Madreporic body rather small, situated midway between center and inner edge of interradial plate; shape very broadly oval; striations coarse, irregular.

Color in life: marginal plates orange; paxillar area lemon yellow. (Young specimen.)

Anatomical notes.—Anal aperture present. Intestinal cœcum very large, consisting of a small subcircular central portion and four main radiating divisions the tip of each being smaller and bifid. Intestinal cœcum with its branches more capacious than dorsal stomach (less hepatic cœca). Aperture from intestinal cœcum into dorsal stomach wide. Dorsal stomach sharply differentiated from ventral.

Hepatic cœca large, extending halfway to tip of ray. Each consists of a smooth-walled ventral half, like a trough, the upper half being wider and divided with dorso-ventrally plicate walls. Ventral stomach small with stout retractor muscles. Gonads in a single thick tuft on either side of the membranous interradial septum. Polian vesicles large; apparently one on each interradius. No superambulacral plates. Ambulacral ossicles small and crowded. First pair greatly enlarged, each with a high rounded crest. Between these crests run transversely a thick muscle band. The enlargement of the first pair of ambulacrals with the accompanying development of the dorsal transverse muscles is undoubtedly connected with the movement of the combined mouth plates. These, being angular, almost completely close the actinostome, and the small marginal spines completely close the opening. Owing to the small size of the actinostome the stomach is probably protruded, as in *Asterias*, an assumption to which weight is given by the strong retractor muscles. The enlargement of the first pair of ambulacrals is abrupt, and so noticeable as to form a good generic character. The same enlargement occurs, but in a less degree, in *Asterodon singularis* (Müller and Troschel). Tube feet small, with sucking disks. No deposits in walls.

Variations.—Variation in this species is comparatively slight. The sides are a trifle more arcute in some individuals than in others. The number of marginal plates varies, with size, from five to a ray (eleven to side of body) in a specimen with R=7.5 mm. to eight in the type with R=21 mm. The granulation is a little coarser on marginal plates in one or two specimens than in type, and the actinal spinulation is longer and closer (stations 4312, 2907). Small specimens have fewer spinelets to actinal and abactinal plates and the papular areas are much smaller. In the smallest specimen, mentioned above, there are about five adambulacral spinelets, two of which stand on the furrow margin, the marginal plates are extremely massive, and the largest radial paxillæ have ten to fifteen spinelets.

Type.—Cat. No. 22333, U.S.N.M.

Type-locality.—*Albatross* station 4313, vicinity of San Diego, 92 to 243 fathoms, gray sand, broken shells.

Distribution.—Monterey Bay to San Diego, California, 43 to 284 fathoms.

Specimens examined.—Eleven, from the following stations:

Specimens of Odontaster crassus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2892......	Santa Barbara Channel, California.	284	yellow mud......................	1	U. S. Nat. Mus.
2907......	Off Point Conception, California.	44	fine gray sand...........	1	Do.
2981......	Off San Nicholas Island, California.	45	coarse gray sand, broken shells..	1	Do.
4311......	Off San Diego, California.....	110-143	green mud, fine sand...... ...	1	*Albatross*, 1904.
4312......	.....do......................	135-95	fine greenish gray sand, rocks...	1	Do.
4313......	.....do......................	92-243	gray sand, shells, rocks..	1	Do.
4543......	Monterey Bay, California....	118-53	rocky....................... ...	1	Do.
4553......	.....do......................	74-65	rocks.........	1	Do.
4555......	.....do......................	66-69	green mud, rocks.....	1	Do.
XXI-2...	San Pedro, California	43	beach worn pebbles and stones, broken shells.	2	University of California.

Remarks.—*Odontaster crassus* is the North Pacific representative of *O. grayi* (Bell), to which it is very closely related, and with which it may ultimately have to be united, if the differences which are believed to exist are not constant. *O. grayi* is found in the region of the Strait of Magellan and Falkland Islands.

In *grayi* the paxillar spinelets number about the same as in *crassus*, but the spinelets are shorter than or subequal to tabulum, while in *crassus* they are slightly longer. In a specimen of *grayi* which I examined at the Museum of Comparative Zoölogy, in Cambridge, the primary basal plate is only a trifle larger than the others; in *crassus* it is much larger. This difference may be due entirely to age. In *grayi* there are two furrow spinelets and four or five, rarely six, actinal adambulacral spinelets, in about two rows; in *crassus* there are six or seven spinelets in three rows (or without order). In *grayi* the recurved tooth is slightly shorter, and thicker on the outer part (less attenuate distally), and the suboral spinelets are only two or three to each plate; in *crassus* the tooth is distally attenuate and quite sharp, and there are five to eight suboral spines to each plate. In *grayi* the innermost marginal mouth spinelets are larger than the middle ones; in *crassus* the marginal spinelets diminish markedly in length from the middle, so that the innermost spinelets are much smaller than the middle ones, and relative to the length of the tooth much smaller than the inner spinelets of *grayi*, which are at least half as long as the tooth (those of *crassus* being about one-fourth as long as tooth).

In this report Verrill's groups *Acodontaster*, *Gnathaster* (Sladen, restricted), and *Odontaster* are united to form a single genus, which takes the oldest name, *Odontaster*.

Family GONIASTERIDÆ Forbes, 1841 (part).

Goniasteridæ Forbes, A History of British Starfishes, etc., 1841, p. 77 (*Asterina, Palmipes, Goniaster*).—Verrill, Trans. Conn. Acad., vol. 1, 1867, p. 343.—Perrier, Révision des Stellérides, 1875, p. 185 (includes also Oreasteridæ, Asteropidæ, *Porania*).—Viguier, Squelette des Stellérides, 1879, p. 166 (includes also Linckiidæ [part], Oreasteridæ, Asteropidæ).—Verrill, 1899, p. 145.—Fisher, 1906, p. 1045.

Pentagonasteridæ Perrier, Mém. sur les Étoiles de Mer, etc., 1884, p. 231.—Sladen, *Challenger* Asteroidea, 1889, p. 260.—Perrier, 1894, p. 336.—Ludwig, 1897, p. 157; 1905, p. 106.

Pentacerotidæ Gray (part), Ann. and Mag. Nat. Hist., vol. 6, Dec., 1840, p. 275 (included Oreasteridæ, Goniasteridæ, Linckiidæ, Echinasteridæ, *Uniophora, Asterope, Nepanthia*).

Antheneidæ Perrier, 1884, and authors.

Phanerozonia with thick and massive marginal plates, large disk, usually conspicuous primary apical plates, and tessellate abactinal and actinal intermediate plates; abactinal plates polygonal, circular, or stellate, sometimes united by internal radiating ossicles, or forming a close mesh with numerous secondary intermediate plates; the plates may bear a central tabulum, paxilliform in structure, or may be simply flat, naked, or covered with granules, or bear an enlarged spine. Papulæ usually confined to radial areas. The plates may be obscured by a tough skin, of varying thickness, which is superficially smooth, or covered with granules, or granules and pedicellariæ. Tube feet with large sucking disks. Superambulacral ossicles present, rudimentary, or absent. Pedicellariæ foraminate, excavate, or bivalved.

Remarks.—The vicissitudes undergone by this group are indicated in a general way by the synonymy. When Forbes instituted the family in 1841, in his notable work A History of British Starfishes, he included only *Asterina, Palmipes,* and *Goniaster.* The first two genera belong to a different order, and the group was obviously quite unnatural. About the same time Gray published A Synopsis of the Genera and Species of the Class Hypostoma (*Asterias* Linnæus), and included such genera as were then known in a large and unnatural family, Pentacerotidæ, which comprised the Oreasteridæ, Goniasteridæ, Linckiidæ, Echinasteridæ, *Asterope, Uniophora,* and *Nepanthia.* This family was evidently built around *Culcita* and *Oreaster* as a nucleus. In 1867 Verrill adopted the name Goniasteridæ, including the following genera: *Oreaster, Nidorellia, Paulia, Asterope, Parasterina* [*Patiria*], *Asterina* [*Asteriscus*]. The family in that sense was not equivalent to the present Goniasteridæ, but Verrill evidently had other genera as well in mind. In 1875, Perrier, in the Révision des Stellérides, excluded *Ferdina* (Linckiidæ), and the various forms of Asterinidæ adopted by Verrill, his family being equivalent to the Goniasteridæ as here used, with the addition of the Oreasteridæ, Asteropidæ, and *Porania.*

Viguier (1879) in his Squelette des Stellérides modified Perrier's classification including *Fromia, Metrodira, Ferdina,* but excluding *Porania* and all the Asteropidæ except *Asterope* [*Gymnasteria*]. *Porania* and the balance of the Asteropidæ were placed in the Asterinidæ. In 1884, Perrier, in the Mémoire sur les Étoiles de Mer, relinquished the name Goniasteridæ, dividing the family as constituted in 1875 into four, namely, Pentagonasteridæ, Antheneidæ, Pentacerotidæ, and Gymnasteridæ. Sladen (1889) adopted this classification, while expressing his doubts as to the validity of the Antheneidæ (pp. 260, 338). Sladen's Pentagonasteridæ included one genus, *Gnathaster* (=*Odontaster*), which is now placed in a separate family, and it lacked the Pseudarchasterinæ, Antheneinæ, and *Amphiaster.* Perrier, in 1894, (Expéditions Scientifiques du *Travailleur* et du *Talisman*) rearranged somewhat the genera of the Pentagonasteridæ.[a] He excluded *Gnathaster,* as also *Leptogonaster* and *Mimaster,* and its allies, relegating them to the Archasteridæ. While there are reasons in favor of so classifying *Mimaster,* none can be adduced to support such a treatment of *Leptogonaster.* Verrill, in 1899 (Revision of Certain Genera and Species of Starfishes), established two new subfamilies, the Mediasterinæ for *Mediaster, Nymphaster,* and *Nereidaster,* and the Hippasteriinæ for *Hippasteria* and *Cladaster.* He added to the Pseudarchasterinæ *Paragonaster* and *Rosaster,* and separated *Odontaster* and its allies in a distinct family, the Odontasteridæ. He recognized the Antheneidæ with *Anthenea* and *Pseudoreaster,* and placed the Mimasterinæ in his new family Plutonasteridæ. He also definitely reinstated Goniasteridæ as a name, and renamed the "*Goniaster*" *obtusangulus* of Sladen,[b] *Pseudoreaster.*

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[a] It may be noted parenthetically that Goniasteridæ was dropped because the name *Goniaster* was without reason fastened upon *Pseudoreaster obtusangulus* (Lamarck), a species not even mentioned by Agassiz in the original description. Thus the placing of "*Goniaster*" in the Antheneidæ necessitated the new name Pentagonasteridæ.

[b] Most writers have overlooked the fact that Agassiz definitely cited *Asterias tessellata* Lamarck as the type of *Goniaster.* (Mém. soc. sci. nat. Neuchâtel, vol. 1, 1835, p. 145.)

In 1906 (Starfishes of the Hawaiian Islands) I accepted Verrill's classification, but separated *Pseudarchaster* and its allies as a separate family, hoping to reduce the Goniasteridæ to a more homogeneous assemblage. The objection to this course is the presence of a pretty complete series of intermediate forms which render the adequate definition of families extremely difficult.

It would be very convenient to recognize the following families: the Mimasteridæ (*Mimaster, Gephyreaster*); the Pseudarchasteridæ with subfamilies Pseudarchasterinæ (*Pseudarchaster, Aphroditaster, Paragonaster*) and Mediasterinæ (*Mediaster, Ceramaster, Nereidaster, Nymphaster, Rosaster*), and possibly Nectriinæ; the Goniasteridæ with subfamilies Goniasterinæ, Chitonasterinæ, Leptogonasterinæ, and Hippasterinæ; the Antheneidæ (*Anthenea, Pseudoreaster*). To do this would also necessitate the admission that there are no definite family boundaries. For instance, *Pseudarchaster* has been found to possess incipient bivalved pedicellariæ (*Ps. dissonus*). *Pseudarchaster* also has definite superambulacral ossicles and paxilliform abactinal plates. Its near relative *Paragonaster* has (in *P. formosus*) rudimentary superambulacrals and less elevated tabula to the abactinal plates. The structure of the mouth plates of *Gephyreaster* allies that form to *Pseudarchaster*, while the adambulacral armature is not that of the Pseudarchasterinæ, but of the Mimasterinæ; the genus is nearly intermediate. Among *Mediaster* and its allies, *Rosaster* (with rudimentary superambulacrals) approaches pretty closely the structure of *Paragonaster* (with the exception of the pedicellariæ), while *Mediaster* itself (with rudimentary superambulacrals) is almost indistinguishable superficially from some forms of *Ceramaster*. The last group has usually been called either *Pentagonaster* or *Tosia*, and is really intermediate between the Mediasterinæ and Goniasterinæ. Its species have either high or low abactinal tabula, and no trace of superambulacrals. They are closely allied to perfectly typical Goniasterinæ, such as *Tosia* (restricted), *Plinthaster*, and *Pentagonaster*. The line between a restricted family Goniasteridæ and Pseudarchasteridæ would be difficult to draw, although the extremes are very different. In all genera the actinal surface is much more uniform than the abactinal, and the structure of the actinal plates is practically the same.

The fact that *Hippasteria* is usually classed in the Antheneidæ (although according to Viguier, Verrill, and the writer it is closer to typical Goniasteridæ) indicates in a measure that no hard and fast line can be drawn between a restricted Goniasteridæ and Antheneidæ. *Cladaster* Verrill has the abactinal surface exactly like that of the Goniasterinæ, while the actinal is more nearly like *Hippasteria*. *Cladaster*, in fact, is intermediate and may be classed in either group. The only feature in which the Antheneidæ might be said to differ from the Goniasteridæ is in the possession of a thick abactinal skin (which is, however, evidently homologous with the thinner skin of *Anthenoides*, *Leptogonaster*, or *Stellaster*). For the stellatoreticulate structure of the abactinal skeleton is similar to that of *Hippasteria* (but *Cryptopeltaster*, classed by Ludwig as *Hippasteria*, does not have the secondary abactinal plates in the form of connecting ossicles, and *Cladaster* Verrill does not have even secondary abactinal plates). The pedicellariæ are similar in the two groups, but other genera not belonging in either have them (*Anthenoides, Gilbert-*

aster). If one were to use as a family character the abactinal membrane (to which one is practically reduced by elimination), what about *Leptogonaster* and its allies, or *Chitonaster?* These would be equally deserving of family rank. It seems that the characters of the Antheneidæ are really not characteristic in the sense of exclusive and that the family is itself an artificial one.

Consequently the limits of the Goniasteridæ have in this paper been somewhat extended to include the Antheneidæ of Perrier and authors, and *Pseudarchaster* and its close allies. Thus the group corresponds to the Pentagonasteridæ of Sladen (1889) and in addition *Pseudarchaster*, *Aphroditaster*, *Anthenoides*, and *Amphiaster*. The last was classified by Sladen in the Oreasteridæ (a family very close to Goniasteridæ), but its affinities are rather with *Goniaster*. If it were left in the Oreasteridæ, there would be some trouble including it within the family diagnosis.

Within this family the range of outward form is great, between such genera as *Pseudarchaster* or *Nymphaster* on the one hand, and *Hippasteria*, *Anthenoides*, and *Anthenea* on the other. The genera agree in having well developed marginals, large actinal interradial areas, with the intermediate plates flat, tessellated, and fairly regular; block-like adambulacrals with a straight or not very prominent furrow edge; and abactinal plates either flat or tabulate, in mosaic, or variously joined by intermediate plates, but never in the form of isolated paxillæ. The tube feet always have a well developed sucking disk.

The scheme of classification adopted is as follows. The asterisk indicates genera of which I have examined species.

Family GONIASTERIDÆ Forbes, emended.

Subfamily MIMASTERINÆ Sladen.

Genus MIMASTER Sladen.
Genus *GEPHYREASTER[a] Fisher.

Subfamily PSEUDARCHASTERINÆ Sladen.

Genus *PSEUDARCHASTER Sladen.
Genus APHRODITASTER Sladen.
Genus *PARAGONASTER Sladen.

Subfamily NECTRIINÆ Perrier.

Genus *NECTRIA Gray.[b]

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[a] Remarks have already been made concerning the intermediate character of this genus. The abactinal plates and mouth plates recall *Pseudarchaster*, while the marginal and adambulacral plates, with their characteristic armature, are similar to those of *Mimaster*. *Mimaster* itself is the least goniasterid of any genus in the family.

[b] *Nectria* is placed in a separate subfamily on the basis of the intermarginal papulæ. Sladen places the genus near *Mediaster*, but Perrier makes a special subfamily Nectriinæ (1894, p. 333). In 1875 he placed *Nectria* with the Goniasteridæ and in 1878 in the Linckiidæ, from which Sladen removed it in 1889. Perrier and Sladen do not mention the important character of the intermarginal papulæ. Pedicellariæ and superambulacral plates are also present. For further details, see *Nectria*, below.

Subfamily GONIASTERINÆ Verrill.

Genus *ROSASTER Perrier.
Genus *NYMPHASTER Sladen.
Genus *NEREIDASTER Verrill.
Genus *MEDIASTER[a] Stimpson.
Genus *CERAMASTER (Verrill) including PHILONASTER Kœhler.
Genus *PLINTHASTER (Verrill) including *PYRENASTER Verrill.
Genus *LITONOTASTER Verrill.
Genus EUGONIASTER[b] Verrill.
Genus *PELTASTER[c] Verrill.
Genus *TOSIA[d] Gray.
Genus *PENTAGONASTER[e] Gray.
Genus *SPHÆRIODISCUS Fisher.[f]
Genus *GONIASTER Agassiz.
Genus *AMPHIASTER Verrill.
Genus *GONIODISCASTER[g] Clark.
Genus *ICONASTER Sladen.
Genus *ASTROCERAMUS Fisher.
Genus JOHANNASTER Kœhler.
Genus *CALLIDERMA Gray.
Genus *CALLIASTER Gray.
Genus MILTELIPHASTER Alcock.
Genus *GILBERTASTER Fisher.
Genus CIRCEASTER Kœhler.
Genus LYDIASTER Kœhler.
Genus *CLADASTER[h] Verrill.

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[a] *Mediaster* is placed by Perrier in the Astrogoniinæ, that is, the Pseudarchasterinæ. There is much to be said in favor of this classification. Verrill places the genus, along with *Nymphaster* and *Nereidaster*, in a special subfamily Mediasterinæ. There is no subfamily difference between *Mediaster* and *Ceramaster*, and to include the latter in the Mediasterinæ would be to annex species which some writers even now call *Tosia* and *Pentagonaster*. *Ceramaster* forms a perfect connecting link between *Mediaster* and its allies and *Pentagonaster* and its allies. All the genera near *Mediaster* (*Rosaster*, *Nymphaster* and *Nereidaster*) are near the typical Goniasterinæ in the structure of the actinal intermediate, adambulacral, and mouth plates, and in having always true bivalved or foraminate pedicellariæ. These are always lacking in the Pseudarchasterinæ, where the pedicellariæ, if present, are spiniform-fasciolar, or are incipient bivalved, and derived from the former. I have merged the Mediasterinæ with the Goniasterinæ.

[b] Type, *Pentagonaster investigatoris* Alcock. "*Eugoniaster* is related to *Peltaster* but differs in having the abactinal plates all small and similar, and also naked centrally, and in having the marginal plates mostly naked, except around the margin. The large bivalved pedicellariæ are similar in the two genera." (Verrill.) The genus differs from *Plinthaster* in the character of the pedicellariæ, and in the adambulacral armature, which is graded from the furrow to the actinal surface. There are no secondary plates, and the abactinal plates are flat and rounded. The actinal plates are granulated.

[c] *Peltaster* Verrill, 1899, p. 168; type, *P. hebes* Verrill =*Goniaster nidarosiensis* Storm, 1881 (Grieg, Bergens Museums Aarbog, 1905, No. 3, p. 3). I have seen the type in the Yale Museum.

[d] *Tosia* Gray, 1840 (Dec.), p. 281; type, *T. australis* Gray; monotypic. There are numerous specimens of *T. australis* in the Museum of Comparative Zoölogy.

[e] See notes on *Pentagonaster*, beyond.

[f] For diagnosis, see notes beyond.

[g] Notes on some Australian and Indo-Pacific Echinoderms. Bull. Mus. Comp. Zoöl., vol. 52, No. 7, 1909, p. 110. Type, *Asterias pleyadella* Lamarck: see notes below.

[h] *Cladaster* may be, with reason, placed in the Hippasteriinæ. The genus lacks entirely, however, the abactinal secondary plates which are characteristic of the three genera placed in the Hippasteriinæ, as well as the characteristic abactinal and marginal tubercles and bivalved pedicellariæ. The abactinal skeleton therefore does not differ materially from that of *Tosia* or *Pentagonaster*. *Cladaster* could be

Subfamily HIPPASTERIINÆ Verrill.

Genus *HIPPASTERIA Gray.
Genus *EVOPLOSOMA Fisher.
Genus *CRYPTOPELTASTER Fisher.

Subfamily LEPTOGONASTERINÆ Perrier.

Genus *OGMASTER von Martens.
Genus *LEPTOGONASTER Sladen, including ANTHENIASTER Verrill.
Genus *ANTHENOIDES Perrier.
Genus *STELLASTER Gray.

CHITONASTERINÆ new subfamily.[a]

Genus CHITONASTER Sladen.

ANTHENEINÆ new subfamily.

Genus *ANTHENEA Gray.
Genus PSEUDOREASTER[b] Verrill (GONIASTER Perrier, but not Agassiz).

NOTES ON CERTAIN GENERA OF THE GONIASTERIDÆ.

PARAGONASTER.—*Paragonaster* is classified by Sladen in the Pentagonasteridæ while *Pseudarchaster* and *Aphroditaster* are placed in the Archasteridæ. Perrier classes all three in the same subfamily (Astrogoniinæ) of the Pentagonasteridæ. *Paragonaster* is evidently close to *Pseudarchaster*, as the adambulacral armature, mouth plates, actinal intermediate plates, and inferomarginals are very similar in the two groups. The unpaired prominent tooth at the inner angle of the combined mouth plates is a good correlative character to indicate relationship, and is one used by Perrier (1894, p. 337). Verrill (1899, p. 196) also places *Paragonaster* next to *Pseudarchaster* and *Aphroditaster*.

NECTRIA.—Through the kindness of Dr. H. L. Clark, I have received for examination two specimens of *Nectria*, one from "Australia," No. 474, Museum of Comparative Zoölogy, and the other, No. 1932, from "Westernport, Victoria."

The former specimen seems referable to *N. ocellifera* Lamarck, but the latter with R about 80 mm. is possibly a new species, as it differs in having the tabula of the abactinal plates very flaring at the top, hiding the papular spaces beneath, and in possessing numerous abactinal and fewer actinal slender jawed foraminate pedicellariæ. Perrier and Viguier state that the genus lacks pedicellariæ.

The following notes on the anatomy were made from the larger specimen:

The abactinal plates are in the form of relatively very large tabulate parapaxillæ, the crown of which flares greatly and is covered with close set granules. The base is not so large as the crown and is five- or six-lobed. The lobes of adjacent plates

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classed in the Hippasteriinæ on the basis of the actinal skeleton and the few and heavy adambulacral spines. The pedicellariæ are more characteristic of the Goniasterinæ although of a form not unknown in the Hippasteriinæ (as, for example *H. californica*). The two aberrant genera *Gilbertaster* and *Cladaster* have been here classed at the end of the Goniasteriinæ, rather than within the Hippasteriinæ. If other species are discovered which disprove the value of the abactinal features referred to, it will be well to replace *Cladaster*, at least, in the Hippasteriinæ.

[a] The unusual characters of *Chitonaster* fully warrant its segregation in a separate subfamily.

[b] *Pseudoreaster* Verrill, 1899, p. 148; type, *Asterias obtusangulus* Lamarck.

do not touch except on outer half of ray but are joined by internal radiating ossicles as in *Mediaster,* there being four to six radiating from each plate. The ossicles are fairly large, except on outer part of ray. In the large triangular meshes left by the ossicles papulæ emerge, but it is not possible to determine the number. On the side of many of the tabula, usually obscured by the overhanging rim, is a curious pedicellaria with three to six slender curved jaws, about as long as the height of the marginal granules. On the actinal surface, somewhat similar pedicellariæ occur on a few intermediate and adambulacral plates near the mouth plates. These have two, three, or four very slender, slightly tapering jaws.

A highly important feature of the anatomy of *Nectria* is the presence of papulæ between the marginal plates. Near the base of the ray there appears to be more than one to an area, but on the outer part there is only one. The series ceases at about two-thirds the length of ray.

The adambulacral armature and mouth plates are essentially goniasterid. In the Victorian specimen there are three longitudinal series of robust truncate subprismatic or quadrate spinelets to each plate and about three in each series. The character of the armature is not unlike that of *Mediaster* and some species of *Ceramaster.*

Superambulacral plates are present but not very well developed. They abut against the lower end of the ambulacral ossicles and against a single row of spaced supplementary internal intermediate plates, apparently distinct from the regular actinal intermediate plates. Proximally some of the superambulacrals abut directly against the actinal intermediates.

Interbrachial septa made up of large flat imbricated plates. First ambulacral ossicle enlarged. Tube feet with large sucking disks and double ampullæ. Actinal intermediate plates imbricated internally, arranged in chevrons.

Nectria agrees with typical Goniasteridæ in the tabulate structure of the abactinal plates, the form of the pedicellariæ, and in the character of the adambulacral, mouth, and actinal intermediate plates, but differs from the Goniasterinæ in having a definite series of papulæ between the two series of marginal plates. The genus seems to be most nearly allied to *Mediaster,* but on account of the presence of intermarginal papulæ is placed in a separate subfamily, the Nectriinæ, Perrier 1894. Perrier, however, failed to designate the really important character which distinguishes *Nectria* from other Goniasteridæ.

Rosaster.—I have examined Perrier's types in the Museum of Comparative Zoölogy. Verrill places the genus near *Paragonaster,* but I think it is much nearer *Nymphaster,* and well within Verrill's Mediasterinæ. Perrier states that no pedicellariæ occur, but on the actinal surface of one of his types (No. 450, Coll. Mus. Comp. Zoöl.) in two interradii there is a good-sized spatulate foraminate pedicellaria whose expanded jaws reach nearly across the plate. A smaller specimen (R = 16 mm.) in the Stanford Collection (received from the Museum of Comparative Zoölogy) also has two conspicuous ventral pedicellariæ. Rudimentary superambulacral plates (few in number and of very small size) are present.

As compared with *Nymphaster,* the radial paxilliform plates are higher and more spaced, and the interradial plates are slightly tabulate, not flat, as in *Nymphaster.* Marginal plates of *Rosaster* have deep grooves between them, but no spinelets in the grooves. In *Nymphaster* these plates have no abrupt furrow, at least in the dorsal series, being like *Mediaster*. The adambulacral armature differs from that of *Nymphaster* in having on the surface of the plate spaced from furrow series a row of two or three stouter and longer tapering spines, one of which is larger than the other two. The furrow spinelets are long, slender, compressed, and four or five in number. The general facies of this species, as well as the character of the pedicellariæ, ally it to *Mediaster* rather than *Pseudarchaster*.

Plinthaster Verrill and Pyrenaster Verrill.—The type of *Pyrenaster* Verrill (1899, p. 166) is *Pentagonaster dentatus* Perrier (1884, p. 242). According to Verrill *Pyrenaster* "is distinguished from *Tosia* and *Pentagonaster* especially by the existence of smaller secondary rounded plates between the primary abactinal plates, and also by the greater specialization of the furrow series of adambulacral spines, for these do not grade into the actinal granulation, as they do in the genera referred to. In this respect the genus is more nearly like *Mediaster*, etc." I have examined the type, *P. dentatus* (No. 408, Coll. Mus. Comp. Zoöl). The only secondary abactinal intermediate plates, on the radial areas, are one or two proximally. There are a few small plates here and there on the center of disk. But *Pentagonaster perrieri* (No. 418, Coll. Mus. Comp. Zoöl.) the type of Verrill's *Plinthaster* (which I consider of generic rank) has secondary plates proximally on the radial areas and also a few on interradial areas. There are more secondary plates than in the type of *dentatus*. The adambulacral armature is of the same character in both species. A difference between the two species (but hardly of generic importance) is to be found in the shape of the pedicellariæ. In *dentatus* the pedicellariæ are few, small, foraminate, with narrow spatulate slightly tapering chisel-like jaws, while in *perrieri* they are much larger with broad jaws (nearly as wide as high) which on the actinal surface fit into slight depressions of the plate. The abactinal pedicellariæ are of the same form (similar to those of *Tosia tuberculata* Gray) but smaller. In both species a few distal superomarginals are in contact, but this is subject to individual variation.

I think there is not sufficient difference to make two genera. The general appearance of the two groups is strikingly similar, and added to this the abactinal, actinal, and adambulacral plates are the same. *Plinthaster* has page priority and should be adopted as the name for the enlarged genus. The following are the species:

Plinthaster perrieri (Sladen).
Plinthaster comptus (Verrill).
Plinthaster nitidus (Verrill).
Plinthaster ceramoideus (Fisher).
Plinthaster dentatus (Perrier).

Verrill refers *Pentagonaster affinis* Perrier to *Pyrenaster*, but as he did not see the type, his specimens were not correctly identified. I have examined Perrier's type (No. 403, Mus. Comp. Zoöl.) and it is not a *Pyrenaster* or a *Plinthaster*. The abactinal plates are wholly granulated and the radial ones are subtabulate. Secondary abactinal plates are evident in a small example about one inch in diameter, but in the type they are not markedly different in size from the primary plates. The species may be referable to *Ceramaster*, although it is by no means typical.

Litonotaster Verrill, 1899, p. 171; type, *Pentagonaster intermedius* Perrier, 1884, p. 243, pl. 5, figs. 5 and 6.—I have seen specimens of the type-species. The genus is remarkable for the thin dorsal integument, few papular pores, and numerous (seven or eight) small furrow spinelets. The marginal plates are unusually small. "Abactinal plates polygonal, flat, thin, closely united, finely granulated, with two or more rows of granules around the edges, but with a small, central, round, naked area, in the type. Papular pores rudimentary, few, small, obscure, not visible except when the plates are denuded; they occur only between the three central rows of plates, in a very circumscribed basal radial area. Actinal plates granulated, rather large, angular, of various forms, not forming regular rows. A small elongated pedicellaria, with two, three, or four spatulate blades, occurs on the center of many of the adambulacral plates and on some of the actinal plates" (Verrill).

TOSIA Gray and PENTAGONASTER Gray.—The type of *Tosia* is *T. australis* Gray; that of *Pentagonaster*, *P. pulchellus;* both montotypic when first characterized. *Stephanaster* Ayres and *Astrogonium* Sladen are synonymous with *Pentagonaster.* There are four specimens of the type species of *Pentagonaster* in the Museum of Comparative Zoölogy. *Stephanaster bourgeti* is excluded from the genus and made the type of a new genus, *Sphæriodiscus.*

It seems necessary to segregate the Australian species in these two genera, as they do not agree with European or American species commonly called *Pentagonaster* and *Tosia.* The latter are now classed in several quite different groups—*Ceramaster, Plinthaster, Peltaster, Litonotaster,* and *Sphæriodiscus.*

Pentagonaster differs from *Goniaster* in lacking abactinal tubercles; in having the last marginal plate of both series enlarged; in lacking abactinal secondary ossicles, and numerous papular pores separated by intermediate granules between the dorsal plates of papular areas; in having abactinal and actinal intermediate plates free of granules except for a marginal series of granules (applies to adults).

Pentagonaster differs from *Sphæriodiscus* in having the last marginal plate of both series (not the penultimate) largest; in having the marginals entirely naked; in lacking the flat granulated abactinal and actinal plates (these being more or less convex and naked in *Pentagonaster*).

Pentagonaster is distinguished from *Tosia* by the enlarged distal marginal of both series (if a marginal is enlarged in *Tosia* it is the last superomarginal only); in the character of the pedicellariæ, which have narrow spatulate jaws (as in *Goniaster*); in *Tosia* they are low, bivalved and wider than high, or are absent altogether.

In the type of *Tosia,* there are very few short bivalved pedicellariæ on the abactinal plates; the actinal surface lacks pedicellariæ, but the plates are naked centrally, there being usually two or even three or four rows of granules around each plate. The adambulacral plates are very like those of *Pentagonaster*—wider than long, with two furrow spinelets, thick and stubby, behind these two more, and then two rows of about three granules each. The abactinal plates are strongly stellate not only on the radial but interradial areas as well. Single papulæ emerge between the lobes of plates, and are distributed all over the disk from center to angles.

The group to which *T. tuberculata* (Gray) belongs is somewhat different—that is, if the specimens in the Museum of Comparative Zoölogy are really Gray's species. The abactinal plates are arranged in radial and parallel rows, but next to radial series in a small specimen, and over most of the petaloid radial area in a larger specimen are wholly granulated, small secondary plates wedged between the primaries. There is a fairly distinct row on either side of the median radial series, and laterally from this for three or four rows the secondaries are numerous but not regular in occurrence. From the inner side the primary plates are slightly stellate with blunt lobes; papulæ are single and absent from interradial areas. Marginal plates centrally bare; actinal intermediate plates mostly subquadrate, covered with good-sized spaced quadrate granules; adambulacral plates slightly wider than long with three or four subquadrate furrow spines and behind these three rows of spines and granules, the armature being graduated into actinal granulation. Many adambulacral plates bear a short rather high pedicellaria with two oblong jaws. The abactinal plates have the central part naked and convex, though some are wholly granulated.

Verrill classifies this species in his restricted *Tosia*. The presence of the abactinal secondary plates as well as of pedicellariæ higher than those of typical *Tosia* suggests the alliance of the form with the less spiny Goniasters. More specimens will be necessary to clear up the limits of *Tosia* and *Pentagonaster*. If any uniting of genera takes place it should be *Goniaster*, *Pentagonaster*, and *Tosia*, not *Tosia* with *Plinthaster* or with *Ceramaster*. The two genera under discussion differ quite widely from either *Plinthaster* or *Ceramaster* in the character of the abactinal and actinal plates which in the Australian-New Zealand forms are naked and convex (but not tabulate) and in the marginal plates which tend to have either one or both series with enlarged distals.

SPHÆRIODISCUS Fisher.[a]—Type, *Stephanaster* [= *Pentagonaster*] *bourgeti* Perrier. Marginal plates thick and wide, few, the penultimate or antepenultimate plate of both series larger than the rest; marginal plates with small spherical granules about the borders, and over general surface are scattered spherical granules sunk in special shallow pits; last two superomarginals in contact. The granules about borders of plates are rather numerous, and in several series on the outer or lateral face of plates of both dorsal and ventral series. Abactinal plates flat-topped, only very slightly tabulate on radial areas, covered with granules; papulæ absent from center of disk and a narrow interradial strip. Actinal intermediate plates wholly granulated. Adambulacral plates wider than long, with four or five furrow spinelets; behind these two or three thicker, shorter spinelets, and then five to eight granules. Pedicellariæ with two slender spatulate blades which rest in inconspicuous depressions. They may occur on all the plates. Contains two species, *Sphæriodiscus bourgeti* (Perrier), Cape Verde Islands, and *Sphæriodiscus ammophilus* (Fisher), Hawaiian Islands.

This genus differs from *Pentagonaster* in having the upper and lower plates wholly granulated; in having not the ultimate but the penultimate or antepenultimate marginals enlarged; in having marginals with spaced granules. The abactinal plates are flat-topped and slightly tabulate on radial areas; the actinals are flat, never convex.

GONIASTER Agassiz.[b]—Type, *A. tessellata* Lamarck, by designation.[c] Verrill (1899, p. 150) has revised this genus. He gives the type as *G. cuspidatus* Gray, to which species the *Asterias tessellata* of Lamarck may be restricted, as it is necessary to dispose of the name. Lamarck's *A. tessellata* included also the previously described *A. granularis* Retzius, 1783. Gray seems to have had a right to consider the name invalidated by *granularis*, so that *cuspidatus* is perhaps tenable. There is no doubt, however, that Agassiz had *cuspidatus* (and not *granularis*) in mind when he placed *tessellatus* as the type of *Goniaster*, for his description of the genus clearly indicates it. By most writers *tessellatus* will be preferred to *cuspidatus* on the ground of priority. Since *tessellatus* was a composite species originally, the elimination of *granularis* would seem to necessitate the restriction of the name to the only available group—that later named *cuspidatus* by Gray.

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[a] Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 171.

[b] Mém. soc. sci. nat. Neuchâtel, vol. 1, 1835, p. 191.

[c] Idem, p. 145.

Amphiaster Verrill.[a]—Type, *A. insignis* Verrill.—Most of the abactinal plates bear an upright blunt tubercular spine nearly as thick as the diameter of the plates, which are roundish or substellate internally, and connected by about six radiating ossicles or secondary plates. The interspaces between the primary plates, the surface of the secondary ossicles, and the base of the tubercles are covered with rather coarse granules. Several papulæ emerge in each of the six areas surrounding a primary plate (these papular areas are covered with granules as noted above). The first superomarginal is largest, smooth, and convex, the second has a heavy tubercle, the third is like the first, the fourth like the second, and the next three very strongly convex. The inferomarginals are similarly disposed. The edges of the plates, which are subcircular, as well as the small interpolated intermarginals are granulated. Nearly all the granulated actinal intermediate plates have prominent tubercles smaller than those of dorsum. Each adambulacral has a prominent actinal blunt tubercular spine (smaller than those of actinal intermediate plates), and a furrow series of three or four blunt, straight spinelets, as long as the actinal but slenderer.

This genus is more nearly related to *Goniaster* than to any in the family Oreasteridæ.

Goniodiscaster.—This genus was named by H. L. Clark[b] for "*Goniodiscus*" *pleyadella* (Lamarck). The old name *Goniodiscus* Müller and Troschel being untenable,[c] was changed by me to *Goniodiscides*, with *G. sebæ* as type. Unfortunately *G. sebæ* and *G. studeri* are young *Culcita*,[d] so that *Goniodiscides* along with *Randasia* Gray becomes synonymous with *Culcita*. But "*Goniodiscus*" *pleyadella* (including *Pentagonaster validus* Bell) is not a young *Oreaster*, as Perrier[e] suggested. It seems to be related to *Goniaster*. There is a close granulation all over the test, but judging from the dried specimen examined, no skin, such as characterizes *Anthenoides*. Although the papulæ are in areas on the disk, the same holds true in adult *Goniaster*. The pedicellariæ are minute pincers and small bivalves. In adults the third or fourth marginals from apex of ray are swollen slightly. Abactinal plates strongly stellate, but there are no intermediate secondary plates, as in *Goniaster*, and no marginal tubercles, only a single short tubercle on each of the five primary (?) radials. A plate on either side of the interradial line is enlarged. Adambulacral plates frequently have a good-sized pincer-shaped pedicellaria with tapering jaws as high as the actinal spinelets.

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[a] Trans. Conn. Acad., vol. 1, pt. 2, April, 1868, p. 372.

[b] Bull. Mus. Comp. Zoöl., vol. 52, No. 7, March, 1909, p. 110.

[c] See Fisher, Bull. U. S. Fish Comm. for 1903, pt. 3, 1906, p. 1070.

[d] Clark, Bull. Mus. Comp. Zoöl., vol. 51, April, 1908, p. 281.

[e] Révision des Stellérides, p. 232.

Leptogonaster and **Antheniaster**.—About the only difference between *Leptogonaster* Sladen and *Antheniaster* Verrill is the wider distribution in the latter of secondary abactinal plates. *Antheniaster epixanthus* Fisher varies considerably, however, in the number of abactinal secondary plates. Young specimens have no more than the adradial row, described by Sladen (1889, p. 330), in the type of *Leptogonaster crispatus*. The character of the abactinal plating, the granulation, actinal interradial areas, and especially the adambulacral armature and abactinal membrane are essentially alike in both species, or not different enough to warrant two genera. *Anthenoides* is the nearest relative. Its differences are brought out in the key. As Professor Verrill classed my *epixanthus* in *Antheniaster*, I have felt justified in using that species for comparison. I now think it is a *Leptogonaster*, intermediate in respect to the abactinal plating between *crispatus* and *sarissa* (Alcock) and differing specifically in details of abactinal and marginal granulation, in the adambulacral armature, and distribution of pedicellariæ.

Ogmaster.—It is rather curious that this genus should have been classed next to "*Goniodiscus*," as its appearance is so unlike any species of that group. In the specimen in the Museum of Comparative Zoölogy (467) the abactinal membrane must be very thin, for it is scarcely apparent in the dried specimen. There are no secondary abactinal plates, and only the plates of the papular areas have slight lobes. There are no granules on any plates but the adambulacrals and mouth plates. This agrees with Gray's figure[a] and description[b] of "*Dorigona Reevesii*," which is the same as *Ogmaster capella*. Sladen's comparison of the genus with *Stellaster* in his key (1889, p. 264), stating that the test is overlaid by a granulous membrane, is not only misleading, but is contradicted in the very next line. There is no particular similarity between *Stellaster* and *Ogmaster*.

KEY TO THE KNOWN GENERA OF GONIASTERIDÆ.

- I. Abactinal plates tabulate on the radial areas and often paxilliform, never flat nor covered with a continuous membrane.
  - a^1. Superomarginal plates not contiguous on the rays, one or more series of abactinal plates reaching the terminal plate (occasionally a few distal plates in contact).
    - b^1. Abactinal plates stellate with paxillæ; actinal intermediate areas with imbricating plates in transverse series bearing paxilliform groups of spines........................*Mimaster* Sladen.
    - b^2. Abactinal plates with tabulate paxilliform plates; actinal intermediate areas with imbricating plates bearing coördinate granules or spinelets.
      - c^1. An unpaired (but not recurved) median tooth common to each pair of mouth plates; pedicellariæ when present fasciolar, rarely valvular; superambulacral plates present, though frequently very small.
        - d^1. Adambulacral armature: furrow series radiating, subpalmate; actinal spines in a coördinate group, frequently one slightly enlarged, appressed; inferomarginals usually with a few appressed enlarged spinelets.
          - e^1. Several series of abactinal plates extending far along ray and usually more than one attaining the terminal plate; rays fairly broad; superambulacral plates fairly well developed; pedicellariæ pectinate, fasciolar, or valvular..*Pseudarchaster* Sladen, p. 179.
          - e^2. Superomarginal plates of ray separated by single series of roundish or quadrate granulated (not paxilliform) plates; superambulacral plates rudimentary.[c] No pedicellariæ. *Paragonaster* Sladen.
        - d^2. Furrow series of spines not radiating or subpalmate.

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[a] Synopsis, pl. 7, fig. 3, 3*a*.

[b] *Idem*, p. 7.

[c] Superambulacral plates rudimentary in *Paragonaster formosus* (Verrill).

e^1. Adambulacral armature in longitudinal series parallel to furrow; furrow spines numerous; actinal interradial areas small, and postadambulacral plates with fascioles; marginal plates without conspicuous channels between .... *Aphroditaster* Sladen.

e^2. Adambulacral armature a compact group of similar spines in more or less evident transverse series; furrow spines two or three; actinal interradial areas large with numerous imbricating plates covered with coördinated compact groups of numerous short spinelets, leaving narrow interradial channels; marginal plates with conspicuous intervening channels .... *Gephyreaster* Fisher, p. 175.

c^2. No unpaired median tooth to each pair of mouth plates; pedicellariæ when present low bivalved, or higher with two or more spatulate jaws; superambulacral plates rudimentary or absent.

d^1. Abactinal plates connected by independent internal slender regular radiating ossicles over the papular area; rudimentary superambulacral plates present.

e^1. Abactinal plates medium-sized or small, roundish, not developed into very large cylindrical tabula; marginal plates conspicuous; bivalved or two-jawed spatulate pedicellariæ; adambulacral spinelets more or less prismatic in longitudinal series, numerous; no intermarginal papulæ; no internal supplementary actinal intermediate plates. *Mediaster* Stimpson, p. 196.

e^2. Abactinal plates lobed, very large with large cylindrical tabula bearing coördinated granules; marginal plates comparatively small; pedicellariæ when present with two to six slender upright jaws; supplementary internal actinal intermediate plates in neighborhood of the ambulacrals; intermarginal papulæ .... *Nectria* Gray.

d^2. Abactinal plates without internal slender radiating connecting ossicles; the plates of the papular areas slightly to conspicuously lobed. No superambulacral ossicles.

e^1. General form stellate frequently with long rays, a single series of abactinal plates reaching the tip of ray, or the few distal superomarginals in contact medially; pedicellariæ high and spatulate .... *Nereidaster* Verrill.

e^2. General form pentagonal, never with long rays; two or three superomarginals sometimes in contact medially; pedicellariæ, if present, small bivalved, or with two or three spatulate jaws, but not high and spatulate .... *Ceramaster* Verrill, p. 204.

a^2. Superomarginal plates contiguous throughout most of ray, the more or less tabulate abactinal plates being confined to disk; slender spatulate pedicellariæ.

b^1. Abactinal plates only slightly tabulate, granulate. No enlarged actinal adambulacral spines; furrow spinelets not very regular nor spaced from actinal; pedicellariæ all small; no rudimentary superambulacral plates .... *Nymphaster* Sladen.

b^2. Abactinal plates of radial areas strongly tabulate, covered with short spinelets rather than granules; furrow spinelets long, regular, and spaced from actinal; one or two enlarged actinal adambulacral spines; a few comparatively large slender spatulate actinal pedicellariæ; rudimentary superambulacral plates .... *Rosaster* Perrier.

II. Abactinal plates only exceptionally tabulate (*Ceramaster*); usually flat or convex, roundish, polygonal, or stellate; smooth, granulous or spiny; in mosaic, with or without secondary intermediate plates which do not form, with the primaries, a close reticulated skeleton.

a^1. Body *not* covered by a smooth or granulous membrane, nearly or quite obscuring the abactinal plates.

b^1. Abactinal plates with upright spines or tubercles of conspicuous size, but no low bivalved pedicellariæ; pedicellariæ, when present, spatulate or like miniature sugar tongs; more than a pentagon of five tubercles on disk.

c^1. No large sharp or blunt actinal intermediate or adambulacral spines; armature of adambulacral plates graduated into actinal granulation .... *Goniaster* Agassiz.

c^2. Adambulacral plates with one or more conspicuous sharp or blunt movable or rigid spines on their actinal surface; adambulacral armature not graduated.

d^1. Small granulated plates and granules between primary abactinal plates, each of which bears a large smooth conical tubercular spine; actinal intermediate plates each with a conspicuous upright blunt spine; scattered intermarginal plates .... *Amphiaster* Verrill.

d^2. No secondary abactinal plates; no intermarginal plates.

e^1. Actinal intermediate plates without spines, or with only low tubercles; plates at least centrally bare; the smooth marginals with one or more rigid spines or tubercles.

f^1. Disk flat but fairly thick; no abactinal pedicellariæ; actinal spines without swollen multifid or bifid points... *Calliaster* Gray.

f^2. Disk very thin, rigid, flat; actinal spines with swollen multifid or bifid points; spatulate pedicellariæ on both surfaces of body......................... *Mitteliphaster* Alcock.

e^2. Actinal intermediate and inferomarginal plates with appressed movable sharp spines; all plates granulated; no tubercular marginal spines; radial abactinal spines present in one species... *Calliderma* Gray.

b^2. Only a pentagon of five short tubercles on disk, or more often none; never any abactinal spines on rays; no superomarginal spines.

c^1. Abactinal plates of rays not abruptly and conspicuously larger than those of disk.

d^1. No inferomarginal and actinal intermediate spines.

e^1. Marginal plates of both series not regularly decreasing in size from interradius to apex of ray, but increasing either slightly or markedly. Sometimes the last marginal is enlarged; sometimes the second, third, or fourth plate from the end is largest, and the marginals are graduated in breadth on both sides of this, abruptly toward the apex and very gradually toward a point between the enlarged plate and base of ray; the enlarged plate is always either appreciably longer or wider (or both) than the preceding or succeeding plates.

f^1. Pedicellariæ never bivalved; no tubercles on disk; papulæ not in areas, single; outlines of plates distinct; abactinal interradial plates not conspicuously enlarged.

g^1. Last marginals of both series enlarged; abactinal, marginal, and actinal intermediate plates smooth, slightly convex (never tabulate) bordered by a single series of granules.. *Pentagonaster* Gray.

g^2. Not the ultimate but the penultimate or antepenultimate marginal of both series enlarged; abactinal and actinal plates flat and closely granulated; marginals with scattered granules in pits................................... *Sphæriodiscus* Fisher.

f^2. Abactinal interradial plates (four in each interradius) enlarged; five primary radial tubercles on disk, forming a pentagon; bivalved pedicellariæ of small size on abactinal, marginal, and actinal intermediate plates, largest on latter area; abactinal plates with minute pincers also; all plates closely granulated; abactinals stellate (no secondary intermediate plates); papular areas with three to five papular pores (except near end of ray where only one or two), granulated, and bearing one or two minute pincers; actinal interradial areas large; adambulacral plates with five to eight slender graduated marginal spinelets and a row of two or three clavate or oblong rounded granuliform spinelets just behind the furrow series; rays slightly swollen near tip or with parallel sides; third or fourth marginal from apex the largest; outlines of abactinal and actinal intermediate plates not distinct.................................. *Goniodiscaster* Clark.

e^2. The marginal plates evenly graduated in size, or if the ultimate or penultimate is enlarged, only in upper series.

f^1. Numerous distal marginals not united to form long slender rays.

g^1. Secondary plates of small size interpolated between the primary abactinal plates.

h^1. Abactinal plates flat, either smooth or granulated, but not tabulate or paxilliform.

i^1. Abactinal plates small, closely granulated; furrow spinelets not spaced from actinal ones, nor sharply differentiated; bivalved pedicellariæ.
Peltaster Verrill.

i^2. Abactinal plates naked centrally, but surrounded by a single series of granules on radial areas (over interradial areas granules may be only scattered around edge of plate, or absent); adambulacral plates with sharply differentiated furrow series; no bivalved pedicellariæ, but a few small chisel-bladed ones on adambulacral plates.................. *Plinthaster* (incl. *Pyrenaster*) Verrill.

h^2. Abactinal plates tabulate on radial areas, suggesting low paxillæ. Secondary plates present only in adult specimens............. *Ceramaster*[a] Verrill, p. 204.

g^2. No secondary plates on radial areas; sometimes a few on center of disk.

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[a] *C. leptoceramus* Fisher.

*h*¹. Abactinal granules, if present, of usual form.

*i*¹. Abactinal plates of normal thickness, not very thin; papulæ normal, not few or absent; furrow spinelets not unusually numerous.

*j*¹. Abactinal and marginal plates with large spaced granules; adambulacral spines relatively heavy, two in the furrow series, with an enlarged actinal spine; actinal pedicellariæ, with broadly spatulate blades; actinal surface resembling *Hippasteria*.................................*Cladaster* Verrill, p. 221.

*j*². Adambulacral spines not thick and heavy; no conspicuously enlarged actinal adambulacral spine.

*k*¹. Abactinal plates smooth, at least centrally; pedicellariæ when present, bivalved.

*l*¹. Abactinal plates strongly stellate, naked centrally, the smooth part convex and bordered by one or two rows of bead-like granules; distal superomarginal sometimes enlarged (but never the inferomarginal). *Tosia* Gray.

*l*². Abactinal plates round, small, with a single series of skin-covered granules; true bivalved pedicellariæ.........................*Eugoniaster* Verrill.

*l*³. Abactinal plates flat, smooth, save for some small encircling granules on radial areas; actinal plates granulated; furrow spinelets fairly numerous, differentiated, and spaced from actinal adambulacral granules; pedicellariæ modified bivalved with thin jaws.......*Plinthaster* Verrill.

*k*². Abactinal plates, as well as actinals, closely granulated all over.

*l*¹. Abactinal interradial plates not larger than the medioradials; abactinal plates slightly to conspicuously tabulate; general form pentagonal; papulæ single, or if more than one to area, then no granules between abactinal plates; actinal row of adambulacral spinelets not conspicuously thicker than the marginal series; outlines of plates all distinct. *Ceramaster* Verrill, p. 204.

*l*². Abactinal interradial plates larger than medioradials (carinals); abactinal plates strongly stellate, not at all tabulate; whole animal closely granulate, obscuring outlines of plates; papulæ one to five to an area; papular areas granulate, bearing sometimes pincer pedicellariæ; general form stellate; first actinal row of adambulacral spinelets thicker and more granuliform than the rather slender furrow series; numerous minute bivalved pedicellariæ on both surfaces and on marginals. *Goniodiscaster* (young) Clark.

*i*². Abactinal plates very thin, flat, finely granulated but with small central naked area; abactinal integument quite flexible; papulæ rudimentary. Many furrow spinelets...*Litonotaster* Verrill.

*h*². Abactinal granules large, irregular, flat, plate-like; large bivalved pedicellariæ on both surfaces; no prominent spines...................*Gilbertaster* Fisher.

*f*². Marginal plates numerous, and superomarginals contiguous, forming long slender rays; abactinal plates smooth.

*g*¹. Abactinal, marginal, and actinal intermediate plates smooth, bordered by four-sided granules; abactinal granules flush with surface of plates, elongated, and on radial areas occurring only on longitudinal sutures between the plates; on center of disk and interradial areas they completely surround plates; adambulacral plates with about four narrow spines, and behind these, four series graduated to granules; adambulacral armature of the type of *Peltaster* and *Pentagonaster*; pedicellariæ on ventral surface small, with narrow spatulate blades. *Iconaster* Sladen.

*g*². Abactinal plates surrounded by small flush granules; marginal and actinal plates with large spaced tubercular granules; actinal plates bordered by bead-like granules; adambulacral plates with large actinal spinules and divergent furrow series; spatulate, excavate, serrate, "sugar-tongs" pedicellariæ.....*Astroceramus* Fisher

d^2. Appressed, distinct, sharp actinal intermediate spinules, in addition to the close granulation.

e^1. Distal superomarginals contiguous; appressed inferomarginal spines; conspicuous enlarged actinal adambulacral spines; marginal plates forming square edge to disk. *Calliderma* Gray.

e^2. Distal superomarginals not contiguous; no inferomarginal spines; no enlarged adambulacral spines; marginal plates forming rounded edge to disk...... *Johannaster* Kœhler.

c^2. Abactinal plates of rays polygonal, flat, conspicuously larger than those of disk; marginal and actinal plates granular, armed with pedicellariæ, but without spines; no enlarged adambulacral spines; disk large, rays long; superomarginals at first increasing, then gradually decreasing in size.

d^1. With bivalved pedicellariæ (type of *Hippasteria*, *Cladaster*, *Gilbertaster*); abactinal plates irregularly polygonal, bordered by a single series of granules, with or without a few scattered granules on surface; plates or rays abruptly larger than those of disk. *Circeaster* Kœhler.

d^2. With spatulate excavate pedicellariæ; abactinal plates of rays larger than those of disk but transition not abrupt; abactinal plates flat, bordered by single row of granules, and with a few granules and a pedicellaria on surface; otherwise as in *Circeaster*. *Lydiaster* Kœhler.

a^2. Body covered by a membrane, which usually obscures the outlines of underlying plates and which may have a smooth surface (the granules when present being beneath the skin) or may be closely beset with small granules (as *Stellaster*).

b^1. Actinal intermediate areas small; abactinal plates hexagonal or rounded, each with a short obtuse spinelet or tubercle; adambulacral armature a transverse series of three large obtuse spinelets; pedicellariæ if present bivalved............................ *Chitonaster* Sladen.

b^2. Actinal intermediate areas large; abactinal plates polygonal, sometimes somewhat stellate; no spines on abactinal surface, rarely a few short tubercles; adambulacral armature a furrow comb, and on the actinal surface either granules or an enlarged flattened spine; slit-like bivalved pedicellariæ or two-jawed pincer-shaped pedicellariæ.

c^1. Membrane superficially smooth; granules, if present, beneath the membrane.

d^1. Abactinal membrane very thin, without granules; no secondary abactinal plates in the radial areas; no marginal granules or spinelets, nor actinal intermediate granules *Ogmaster* v. Martens.

d^2. Abactinal membrane fairly thick and obscuring (unless dried) the outlines of underlying plates; secondary small abactinal intermediate plates on either side of the median radial series, sometimes more extensively distributed over radial regions.[a]

e^1. Superomarginals without conspicuous granules, spinelets, or pedicellariæ. Actinal interradial areas with slit-like bivalved pedicellariæ in addition to hemispherical granules. *Anthenoides* Perrier.

e^2. Superomarginals with granules or a few short spinelets or only a few small papilliform pedicellariæ; no slit-like bivalved pedicellariæ, but actinal intermediate area with or without papilliform pincer-shaped pedicellariæ. *Leptogonaster* Sladen (incl. *Antheniaster* Verrill).

c^2. Membrane closely beset with very small crowded granules. Abactinal plates polygonal or substellate; inferomarginal plates with a flattened mobile spine; bivalved pedicellariæ flush with surface, frequently several papulæ to an area.............. *Stellaster* Gray.

III. Abactinal plates circular to substellate, separated by numerous secondary plates which are either independent or else join the primary plates forming a close reticulated skeleton; in the latter case, when viewed internally, the secondary plates appear as short rather irregular ossicles passing between the large primary plates, so as to form a sort of heavy reticulum; but superficially they appear as ordinary plates of smaller size; abactinal skeleton not overlaid by a thick skin; a rather thin pulpy membrane sometimes present, partially obscuring the plates; pedicellariæ typically large, bivalved or with spatulate wide or narrow jaws. Adambulacral spines of both series heavy, comparatively few, those of actinal surface of plate always few and heavy; usually robust marginal spines present.. *Hippasteriinæ*.

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[a] Often lacking in very young specimens.

a^1. Abactinal plates entirely covered by large flat circular, quadrate, oval, elliptical, triangular, and polygonal granules, whose edges are more or less free; secondary abactinal plates not forming connecting pieces between primary plates; some of the adambulacral plates with furrow series replaced by a large bivalved pedicellaria.................... *Cryptopeltaster* Fisher, p. 237.

a^2. Abactinal plates not entirely covered by large flat granules whose edges are more or less free; secondary plates forming connecting pieces between the primary plates; no large bivalved pedicellariæ on furrow margins.

b^1. Granules of body sheathed in a thick pulpy membrane and furrow spines three to six in number with remarkably thin, compressed, expanded tips..................... *Evoplosoma* Fisher.

b^2. Granules not sheathed and hidden by a thick pulpy membrane; granules typically forming a single series around the plate; furrow spines one to three in number, not flaring or chisel-like at tip... *Hippasteria* Gray, p. 223.

IV. Abactinal skeleton stellate reticulate, overlaid by a thick skin obscuring the outlines of the plates; marginal plates heavy, beset with large granules, the inferomarginals with large bivalved pedicellariæ also; actinal plates with coarse granules and large pedicellariæ; adambulacral armature, a few (about five) relatively short, slender, furrow spines, and one or more short heavy actinals; all pedicellariæ bivalved.. *Antheneinæ*.

a^1. Abactinal membrane beset with bivalved pedicellariæ and scattered granules; superomarginals, also, with large pedicellariæ; abactinal plates stellate, the secondary plates connecting the lobes to form a regular reticulated skeleton .... *Anthenea* Gray.

a^2. Abactinal surface without pedicellariæ, with a few hemispherical tubercles along radial line, and large hemispherical granules near marginal plates; abactinal plates relatively small, irregular, reticulate; two actinal adambulacral spines; actinal plates very distinct.
Pseudoreaster Verrill.

NOTE ON PEDICELLARIÆ.

Several sorts of pedicellariæ have been mentioned in the foregoing key. To avoid confusion, these will be explained briefly. All the pedicellariæ occurring in the Phanerozonia are of the sessile type—that is, the jaws are not attached to a special basal piece, but spring directly from the plate or from a specialized depression or foramen in the plate.

A. Incipient and pseudo-pedicellariæ. The jaws do not spring from a specialized depression or foramen.
  1. The spinelets stand on separate plates and meet over the suture between the plates.
    1*a*. Spinelets form simple fascioles; *fasciolar*.
    1*b*. Spinelets are more specialized and in definite areas, or are more definitely coordinated into a special apparatus, as two opposed combs; *pectinate*.
    1*c*. The spinelets of a series fuse or widen, and thus form valves; *valvular*.
  2. The spinelets stand usually on one plate, forming a more or less conical group; not found in the Goniasteridæ; *fascicular* or *fasciculate*.

B. Alveolar or tong-shaped pedicellariæ. The jaws spring from a specialized pit or foramen, and vary in size and proportions.
  1. The jaws have no specialized depressions into which they fit when opened; the jaws are higher than wide and often spatulate; *foraminate*, also spoken of as *two-jawed spatulate*, or as *spatulate*.
  2. The jaws are low and wide, with no specialized depression into which they fit when opened. The pedicellariæ are mere slits, or resemble a miniature bivalved shell. This form intergrades with the simple foraminate type of various shapes. It is found in a typical form in *Hippasteria*, *Cryptopeltaster*, *Gilbertaster*, *Anthenea*, and other genera; *bivalved*.
  3. The jaws when opened fit into a specialized depression. This type is best developed in the Linckiidæ, but occurs in *Calliaster*, *Astroceramus*, *Lydiaster*; *excavate* or *sugar-tongs*.

Subfamily MIMASTERINÆ Sladen, 1889.

Mimasterinæ Sladen, *Challenger* Asteroidea, 1889, p. 331.—Perrier, 1894, p. 252.—Verrill, 1899, p. 200.

Genus GEPHYREASTER Fisher.

Gephyreaster Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 171. Type, *Mimaster swifti* Fisher.

Diagnosis.—Related to *Mimaster* Sladen, but differs in having stout tabulate paxillæ with strongly stellate bases by which plates overlap; in character of actinal intermediate plates which, instead of bearing small tufts of spines forming spaced paxillæ, are densely covered with spinelets; in the armature of the mouth plates, which have a peculiar angular marginal series situated between peristome and superficies of plate on the inner end; superambulacral plates present. Marginal plates, adambulacral plates, and their armature, similar to those of *Mimaster*, the first without enlarged spinules.

Remarks.—This genus is erected for the species which I called *Mimaster swifti* in 1905. Since then I have received two additional specimens, and these have convinced me that I was in error in placing the species in that genus. The character of the low tabulate paxillæ resembles *Pseudarchaster*, from which, however, the new genus differs in the form of the adambulacral armature and marginal plates, and to a less extent in the character of the actinal intermediate plates. The large sucking disks of the tube feet also ally *Gephyreaster swifti* to *Mimaster* and *Pseudarchaster* rather than to any genus near *Plutonaster*. It is probable that *Mimaster* has superambulacral plates and that Sladen overlooked them, as is very easy to do in forms where they are feebly developed. The median tooth pointed over the actinostome recalls some species of *Pseudarchaster*. My own opinion is that the present genus is intermediate in many respects between *Mimaster* and *Pseudarchaster*, and I would therefore associate the three genera more or less closely in the system. The resemblance of true *Mimaster* to *Leptychaster* is also great, but the difference in the tube feet is a more important barrier than is commonly supposed. In passing, it might be well to call attention to the discrepancy in this character between *M. tizardi* and *M. cognatus*. The latter has conical tube feet with a little button (as in *Astropectinidæ*) at the tip. *M. cognatus* is really not a *Mimaster* but in all probability a *Leptychaster*. The present genus is also more remotely allied to the *Odontasteridæ*.

GEPHYREASTER SWIFTI (Fisher).

Pl. 30, figs. 1–4; pl. 57, figs. 2, 2*a–c*; pl. 59, figs. 5, 5*a*.

Mimaster swifti Fisher, Bull. Bur. Fisheries for 1904, vol. 24, 1905, p. 301.

Diagnosis.—Rays five. R=114 mm.; r=43 mm.; R=2.65 r. Breadth of ray at base between first and second superomarginals 50 mm. A large specimen. R=140 mm.; r=58 mm.; R=2.5 r. General form large, robust, flattened; rays broad at base, tapering evenly or else slightly arcuately, to a blunt extremity; interbrachial arcs wide, rounded; abactinal surface slightly inflated, sunken in actinal interradial areas. Marginal plates conspicuous, without specialized spines, but resembling very large paxillæ; furrows between plates usually conspicuous. Abactinal paxillæ with stellate imbricating plates arranged in longitudinal series on rays, bearing low stout tabula crowned with numerous granuliform spinelets. Papulæ one, two, or three to each area; six areas about a plate; absent from end of ray. Adambulacral plates with a dense armature of ten to twelve robust subcylindrical spines or spinules, decreasing in size away from furrow; two or three on furrow margin, and the rest in subparallel rows of two or three. Adambulacral and mouth spines are the largest ones on animal. Mouth plates prominent with angular marginal series situated on side of plate between true margin and peristome and with numerous stout coarse spines on the actinal surface. Usually a single large tooth at inner angle of combined plates, with several slightly smaller accessory spines. Actinal interradial areas large, but narrow on rays; plates arranged in interradial or transverse rows, densely covered with spinelets. Superambulacral plates present.

Description.—Abactinal surface varies in the degree of inflation, usually arched on rays and disk. It is covered with fairly large and compact, rather closely placed, tabulate, low paxillæ, which are arranged in rather indefinite transverse oblique rows at the sides on the proximal portion of rays, but are without order on distal half and on central portion of disk. The paxillæ also form not very definite longitudinal rows on basal portion of rays, the mid-radial series being largest and fairly definite as far as middle of ray. On either side of this the paxillæ decrease in size toward margin. These paxillæ are not of the high slender sort characteristic of the Astropectinidæ, but are low, with broad flat tabula (like those of *Mediaster*) crowned with robust clavate or acorn-shaped granuliform spinelets or elongate granules. These spinelets, which vary greatly in shape, from roundish polygonal with a broad dome-shaped or nearly truncate tip to thimble-shaped or even acutely ovoid, form a hexagonal, roundish, or quadrate very slightly convex group of twenty-five to forty on large plates and fifteen to twenty-five on the smaller lateral ones according to size of specimen (largest with R=140 mm.). Those in center are usually shorter than granules about the edge, sometimes smaller, sometimes slightly larger. The photographic figure will give the best idea. In addition to the above, one or two irregular peripheral series of very much smaller, and considerably slenderer papilliform, lanceolate spinelets are placed lower down on the pedicel, and appressed closely to bases of outer robust spinelets, so that they are not usually superficially visible. Superficially the papulæ are easily seen between the paxillæ, two or three to an area in the two largest individuals, usually only one in a specimen with R=74 mm.; six areas about each plate.

Abactinal plates viewed from inner or cœlomic side are seen to be strongly stellate, with usually six, but sometimes only five or four lobes. By these lobes the plates overlap one another after the manner shown by the drawing. They are arranged in regular longitudinal series parallel with the median radial. The manner in which either adradial series overlaps (as seen from the underside) the radial series is shown by drawing. Notice that this is different from the overlapping of the other parallel series. At the proximal end of the regular radial series is an easily distinguishable primary radial plate. Between this and center of disk the plates are smaller, less uniform in size, and irregular in disposition. On the ray the plates decrease very gradually toward margin and distally. Papulæ appear to be all over disk, barring the narrow line of insertion of interradial septum. They are absent from the terminal fifth of ray. Here the plates are less markedly stellate. The arrangement of papulæ is described in preceding paragraph.

Marginal plates conspicuous, but partaking of the nature of large paxillæ, entirely without enlarged spines; a well-defined, narrow, naked groove between superomarginals and abactinal paxillæ. Both series with special raised ridges crowned with coarse granules which increase in size toward center of ridge, where they are quite heavy and similar to very much enlarged spinelets of the paxillæ, though more tubercular and pointed. On inferomarginals the spinelets are still thicker and heavier, and increase in size toward actinal end of plate. Superomarginals, forty to forty-three in number from interradial line to extremity of ray, are much wider than long at base of ray; less so on outer part; with curved upper and lower margins; the raised ridges strongly tumid, and when denuded are about as thick as the adjacent intervening furrows, which are wider in the type than in the other two specimens. A conspicuous longitudinal channel separates the plates of the two series These furrows are not lined with fine spinelets as is usually the case with typical fasciolar channels. The superomarginals encroach upon the abactinal area, forming usually a well-defined border. The spinelets vary more or less but are usually clavate and much larger on lower half of plate, where two to four series on the median line have abrupt conical tips. Terminal plates small in largest specimen, but relatively larger in smallest; about as wide as long, broadest distally; sometimes ovoid, at others roundish; granulose; wedged between last two or three superomarginals.

At base of ray the inferomarginal plates do not correspond always exactly with superomarginals, but in some cases may even alternate. The plates are tumid and form a very even rounded border to actinal area, but are narrower than the corresponding superomarginals (beyond interbrachial arc), hence are nearly to quite quadrate beyond middle of ray; (quadrate in largest specimen, wider than long in other two including type). The granules as a whole are more robust than those of superomarginals, but are similar in character and increase in size toward lower part of plate, being much larger along the median transverse region than on periphery of ridge. The marginal plates are, in appearance, what they are morphologically—very much enlarged paxillæ.

Adambulacral plates, wider than long and rather closely placed, so that the peculiarly characteristic armature forms a dense mass of spines along margins of furrows. On each plate are ten to twelve robust, subcylindrical, untapered, occasionally slightly compressed, truncate or round-tipped spines which decrease in size as they recede from the furrow and are arranged either in five longitudinal series of two, four series of three, or may be without regular order on outer half of plate. Furrow series is commonly oblique and composed of three instead of two spines; or one may stand on center of margin and two just behind it. On outer end of plate five or six robust much smaller spinelets (even granules sometimes) form a group about the spines along the border of plate. These outermost spinelets are sometimes hard to distinguish from those on adjacent actinal intermediate plates. The spinulation is so dense all along the adambulacral plates that it is difficult to distinguish the individual plates.

Mouth plates comparatively large, rather prominent actinally, this appearance being accentuated by a depression in the interradial area at their outer end. General surface is covered with numerous, robust, prismatic, subquadrate, truncate, short irregular spinules or spines, which increase in size and become more compressed (broad side to furrow) toward the free margin of plate. The true marginal series begins near outer (aboral) end, high in the furrow, next to first ambulacral plate as rather inconspicuous flattened lanceolate or truncate spinelets, which rapidly increase in size toward inner angle. These form a group or an angular series (the apex being next to peristome), one part of which curves upward (as viewed from actinal surface) along the furrow margin of plate, while the other, closely parallel for a way, proceeds upward to the inner or dental angle of the plate. At this inner or dental angle is a large median spine directed over actinostome, as in *Pseudarchaster.* This spine is either flattened and broad at tip (type), flattened without being conspicuously widened (station 4784), or truncate and somewhat pestle-shaped (station 2879). On either side of the median tooth is a similar spine, and those on actinal surface seem to grade into these dental spines. The median spine is not always present. On the outer part of the plate of the largest specimen the small irregular but very robust spinelets have a truncate concave tip. There is so much variation in the minor details of the armature in the three specimens that it seems useless to describe in detail the actinal surface of these plates. The illustration (pl. 57, fig. 2) will give a better idea.

Actinal interradial areas large and paved with superficially elliptical or oblong plates arranged in series from adambulacrals to inferomarginals. There is one of these series to each adambulacral (as far as the plates extend) with occasionally an extra series. The plates of a series imbricate, the outer end underlying the inner end of the next exterior plate, but although the independent series are close together, the plates do not appear to overlap along the longitudinal axis of ray. On the rays the intermediate areas are narrow, not broad as in *M. tizardi.* One series of plates (longitudinal) extends nearly to tip of ray; the second series extends only half the length of ray measured from first marginal plate; a third series about one-fourth or to eleventh inferomarginal. Between this point and interradial line the number of plates increases very rapidly. Each plate is slightly convex and is covered with coarse spinelets, which are largest in center of plate, clavate, prismatic, quadrate, or pinched, with subtruncate or rounded tips. The peripheral spinelets are smaller truncate, pinched or papilliform, and bend over the shallow channels between the transverse series of plates. These are similar to the "post-adambulacral fascioles" of *Pseudarchaster,* but the grooves lead all the way to the marginals. A few of the intermediate plates on largest specimen have four central spinelets equal and closely grouped to resemble a pedicellaria; I doubt its being one.

Madreporic body inconspicuous about midway between center of disk and inner edge of marginal plates or a little nearer center than margin. It is small circular convex, partly overhung by paxillæ, a large primary basal paxilla occurring on the adcentral side. Striations fine, ridges coarse centrifugal, branching and more or less sinuous.

Anatomical notes.—Superambulacral plates present though small. They are fitted into the angle between lower end of ambulacral and actinal intermediate plates and are very inconspicuous unless treated with caustic potash. They are absent from the first ambulacral and at the end of the ray for a considerable number of plates. The longest superambulacrals are less than one-third height of exposed surface of corresponding ambulacral. Gonads in a thick much-branched tuft on either side of interradial septum. Anus present, small and inconspicuous. Intestinal cœcum large, divided into two digitate halves, one with four the other with six palmately arranged lobes. Strong retractors of stomach present. Interradial septa single, thick and apparently muscular, but containing no calcareous deposits. Tube-feet large in two rows, with broad sucking disk; no deposits.

Type.—Cat. No. 22332, U.S.N.M.

Type-locality.—*Albatross* station 4253, Stephens Passage, Alaska, in 131 to 188 fathoms; rock and broken shells. (1903 coll.)

Distribution.—From the end of the Aleutian Chain to Washington, 34 to 188 fathoms; on rocks.

Specimens examined.—Three; besides the type, one from station 2879, off Washington, 34 fathoms, rocks; (U. S. Nat. Mus. coll.); one from 4784, near Attu Island, Aleutian Chain, 135 fathoms. (*Albatross*, 1906 coll.)

Subfamily PSEUDARCHASTERINÆ Sladen 1889 (extended).

Pseudarchasterinæ SLADEN, *Challenger* Asteroidea, 1889, p. 109.—VERRILL, Trans. Conn. Acad., vol. 10, 1899, p. 187 (extended).

Astrogoniinæ PERRIER (part), Expéd. sci. du *Travailleur* et du *Talisman*, 1894, pp. 337, 338.

Pseudarchasteridæ FISHER, Bull. Bur. Fisheries for 1904, vol. 24, 1905, p. 303; idem, 1903, pt. 3, 1906, p. 1036.

Genus PSEUDARCHASTER Sladen.

Pseudarchaster SLADEN, Narr. *Challenger* Exp., vol. 1, 1885, p. 617; *Challenger* Asteroidea, 1889, p. 109. Type, *Ps. discus* [a].—VERRILL, Trans. Conn. Acad., vol. 10, 1899, p. 189.

Astrogonium (part) PERRIER (not of Müller and Troschel), Expéd. sci. du *Travailleur* et du *Talisman*, 1894, p. 338.

Diagnosis.—Abactinal plates paxilliform, usually more or less stellate, arranged in radial rows, the median largest; papulæ usually six about a plate, commonly absent from distal half of ray. Marginal plates thick, moderately large, paired, with fasciolated grooves between them. Superomarginals usually separated throughout length of ray, one to three series of paxillæ attaining terminal plate. They are covered with close granules or small, crowded appressed spinelets, the inferomarginals sometimes with enlarged appressed spinules in a transverse series or group. Adambulacral plates usually broad with convex or angular furrow margin, and few furrow spinelets in palmate series. Actinal intermediate plates numerous, arranged in rows running from adambulacral to inferomarginals often also forming parallel longitudinal series; these plates either simply granulous, or with slender spinelets, often with an enlarged spinule on many plates. Mouth plates large and prominent, frequently with an odd median spine at inner angle of combined plates. Pedicellariæ sometimes present, when they are either pectinate (formed of two opposing combs of spinelets over a transverse suture between actinal intermediate or adambulacral plates) or are bivalved and evidently developed from the foregoing sort. Incipient pedicellariæ or postadambulacral fascioles are present on actinal interradial areas and readily develop into pectinate pedicellariæ. Small pincer-like pedicellariæ present rarely. Superambulacral plates present, often but feebly developed. Tube feet with a well developed sucking disk.

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[a] No species is mentioned in the original description. Strictly, the genus had no status till 1889; *Ps. discus* is the first species.

KEY TO THE SPECIES OF PSEUDARCHASTER HEREIN DESCRIBED.

a^1. No trace of bivalved pedicellariæ on first row of actinal intermediate plates or of pectinate pedicellariæ with conspicuously widened spinelets; superambulacral plates not well developed; actinal intermediate and marginal plates covered with short swollen spinelets or granules.
  b^1. Paxillæ crowded; granulation of marginal plates close, the inferomarginals with low hexagonal or squamiform granules; abactinal paxillar area narrow on rays; actinal spinulation coarser and more granuliform; rays longer, disk smaller; postadambulacral fascioles........*parelii*, p. 180.
  b^2. Paxillæ usually well spaced with prominent papulæ between; superomarginals not prominent, with spaced granules, a few conspicuously enlarged at outer end of plate; inferomarginals with prominent enlarged spinules and spaced papilliform spinelets; rays broad and usually short; actinal spinulation more delicate and spaced; pectinate pedicellariæ sometimes present—simply more fully developed postadambulacral fascioles..............................*pusillus*, p. 187.
a^2. Bivalved or bivalve-pectinate pedicellariæ; actinal spinelets rather long and delicate on intermediate plates; superambulacral plates well developed..........................*dissonus*, p. 192.

PSEUDARCHASTER PARELII (Düben and Koren).

Pl. 31, figs. 1, 2; pl. 33, fig. 3; pl. 57, fig. 5.

Astropecten parelii DÜBEN and KOREN, Kongl. Svensk. Vet. Akad. Handl., 1844, 1846, p. 247, pl. 7, figs. 14-17.—M. SARS, Nyt Mag. for Naturv., vol. 6, Heft 2, 1850, p. 161.

Archaster parelii M. SARS, Öfversigt af Norges Echinodermer, 1861, p. 35, pl. 3, figs. 1, 2.—VERRILL, Amer. Journ. Sci., vol. 7, 1874, p. 500; vol. 23, 1882, p. 140; Rep. U. S. Comm. Fish and Fisheries, vol. 11, 1884, p. 543.

Archaster parelii, var. *longobrachialis* DANIELSSEN and KOREN, Nyt Mag. for Naturv., vol. 23, 1876, p. 17; The Norwegian North Atlantic Exp., Asteroidea, 1884, p. 88.

Plutonaster (*Tethyaster*) *parelii* SLADEN, *Challenger* Asteroidea, 1889, pp. 83, 102, 122, 722.—SLUITER, Bijdr. tot de Dierk., Afl. 17, 1895, p. 51.—SLADEN, Trans. Roy. Irish Acad., vol. 31, pt. 3, 1897, p. 78.

Plutonaster parelii BELL, Catalogue of the British Echinoderms in the British Museum, 1892, p. 63.—NORMAN, Ann. and Mag. Nat. Hist. (6), vol. 12, 1893, p. 346.—GRIEG, Bergens Museums Aarbog, 1894-95, No. 12, 1896, pp. 5, 12; Stavanger Museums Aarsberentning for 1896, 1897, p. 37.—LUDWIG, Fauna Arctica (Seesterne), vol. 1, 1900, p. 449 (full synonymy of "*parelii* restricted," to 1897).

Pseudarchaster intermedius SLADEN, *Challenger* Asteroidea, 1889, p. 115, pl. 19, figs. 3, 4; pl. 42, figs. 5, 6.—VERRILL, Proc. U. S. Nat. Mus., vol. 17, 1894, p. 249; Amer. Journ. Sci., vol. 49, 1895, p. 195; Trans. Conn. Acad., vol. 10, 1899, p. 190, pl. 25, figs. 1, 1*a*–*b*.

Pseudarchaster tessellatus, var. *arcticus* SLUITER, Bijdr. tot de Dierk., Afl. 17, 1895, p. 51 (according to Ludwig).

Astrogonium parelii KŒHLER, Bull. de l'Institut océanographique, No. 99, April, 1907, p. 31.

Diagnosis.—Rays five. R = 104 mm.;[a] r = 37 mm.; R = 2.8 r. Breadth of ray at base, 42 mm. Rays well developed, abruptly and arcuately tapering at base, then very gradually to the blunt extremity; interbrachial arcs wide and rounded; abactinal area subplane, only a trifle inflated on center of disk. Abactinal paxillæ small, crowded and regular, about two opposite each marginal plate, and with five to seven polygonal or subprismatic granules surrounded by twelve to fifteen slenderer papilliform spinelets on periphery of tabulum. Abactinal plates with five or six prominent lobes. Marginal plates broad with close-set, flat-topped hexagonal granules. Inferomarginals with a transverse row of small appressed, squamiform, pointed spinules. Adambulacral plates with five or six strongly compressed furrow spinelets, and on actinal surface one or two enlarged spinules surrounded by numerous shorter granuliform spinelets to the number of fifteen to twenty-two, all thick, heavy, and membrane-invested. Mouth plates with median tooth. Actinal interradial areas large; plates covered with rather crowded, swollen, polygonal, papilliform unequal granules, those in center more robust, clavate, with flaring tips. Many plates with a central enlarged spinule. Fasciolar channels or pectinate pedicellariæ between plates adjacent to adambulacrals, these continued toward margin but less conspicuously. Spinelets forming roof of fascioles slender. Superambulacral plates present.

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[a] An unusually large specimen for this species, station 3225.

Description.—Abactinal paxillæ small and crowded fairly regular, largest on proximal radial regions, very crowded and small at ends of rays where only the median radial series attains the terminal plates but the two adradial nearly reach it; one and one-half to two paxillæ correspond to each marginal plate. The larger paxillæ have five to seven polygonal or subprismatic, robust, truncate granules, heavier at tip than at base, and occupying surface of tabulum, while on the periphery are about twelve to fifteen much slenderer papilliform or subprismatic spinelets. The spinelets may be very compactly placed or form a more or less open group. Along the border of the area the paxillæ are compressed, the tabulum being elliptical and crowned with two rows of eight to ten granules in all.

Abactinal plates with five or six distinct lobes by which the plates touch or overlap; toward margin, plates often very irregularly lobed, or without lobes. They are arranged in series parallel with median radial. Papulæ, one to an area, six about each plate; but absent from terminal half of ray, where the plates are without lobes, being irregularly hexagonal or oval.

Marginal plates broad and short, encroaching conspicuously upon both areas. Superomarginals, fifty-eight in number from interradial line to extremity of ray, vary in width, and are wider in interbrachial arc than elsewhere (8.5 to 9 mm. wide in large examples). They form an even bevel, more or less arched on outer part of ray and are covered with regular, close hexagonal granules in five to seven transverse rows which are coarser at the outer (lateral) end of the plate. The marginal granules are smaller and form very regular series. Granulation has appearance of being very regular, compact, and smooth. Grooves between plates invisible from exterior, and probably not functioning as fascioles. Terminal plate medium-sized, obovoid, covered with granules.

Inferomarginals correspond to superomarginals in position, though there is usually one additional plate at tip of ray, and they are a trifle wider. Covered with coarse hexagonal granulation, which increases rapidly in coarseness toward margin of ray. In some specimens the granules are slightly squamiform. In the interbrachial arc the plates bear a median transverse series of four to six flattened lanceolate appressed spinules, which are gradually reduced in size and number along ray, being frequently absent from the last few plates, and only one or two beyond the middle.

Adambulacral plates with an angular furrow margin bearing a palmate series of five or six more or less compressed spinelets, the median (or adoral admedian) the longest and most compressed; tips rounded; lateral spinelets often with flat side uppermost. The furrow series is continued along adoral and aboral margins of plate in three or four spaced, stout, much smaller, papilliform spinelets. On actinal surface one, two, or occasionally three, enlarged very robust bluntly pointed spinules stand in a transverse oblique, or longitudinal series (only one spinule in medium-sized and small specimens). Between them and furrow series is a semicircular row of three or four shorter, blunt, stout, papilliform spinelets, or sometimes very strongly flattened spinelets; these sometimes absent; on outer part of plate are several smaller three- or four-sided unequal clavate spinlets. Exclusive of furrow series there are about fifteen to twenty-two spinules and spinelets to each plate, the outermost very irregular in distribution and on distal part of ray showing a tendency to group themselves about the two or three larger spinules.

Mouth plates prominent actinally, with a bristling armature of robust, short, untapered blunt spines disposed in a marginal and two actinal series. Of the latter one stands on the border of the median suture, while the second, an intermediate shorter irregular series, is located between it and a continuation of the marginal series on the edge adjacent to first adambulacral. These spines are subquadrate, subterete, occasionally spatulate, and are longer on the inner than on outer end of plates. They are also variable in number according to age and locality. The true marginal series consists of about seven robust spines in addition to a large median unpaired spine at the inner angle of the combined plates. The three adjacent to inner angle are usually graduated in size, then the next four are stouter and longer. This is the plan of the furrow series; the spine counts vary.

Actinal interradial areas large, the intermediate plates extending to the tenth to seventeenth inferomarginal, or one-fourth to a little over one-third length of ray measured along side from interradius; plates arranged in rows running from adambulacrals to inferomarginals. From inner side these plates are oval and imbricate with all the surrounding plates. Plates armed with unequal, swollen, more or less crowded granules, those in center robust and clavate, often with slightly flaring tips bent outward, the peripheral smaller, round-tipped, occasionally subprismatic, very unequal and irregular, and radiating over narrow shallow grooves between the plates. These channels lead in an irregular course from the inferomarginal fascioles to those between the adambulacral plates. In some specimens they are more conspicuous than in others, and all are more conspicuous adjacent to adambulacrals where they are often roofed by pectinate pedicellariæ. Many of the plates bear a central enlarged pointed spinule directed toward margin. The number of plates bearing such spinules is variable.

Madreporic body small, situated one-third distance from center to margin; striations very irregular, the ridges between striæ coarse.

Anatomical notes.—Superambulacral plates present, extending along ray as far as do the intermediate plates, and absent from first ambulacral ossicle; they are rather small. Gonads in a single tuft on either side of interradial septum, which is membranous. Anus present. Intestinal cœcum large with ten or eleven radiating, slightly branched divisions. Tube feet with well-developed sucking disks; no deposits.

Variations.—The principal variations have been noticed in the above description. To recapitulate, they concern chiefly the following characters. Rays, which vary in breadth and length, being a little shorter in Japanese specimens, but vary also in Alaskan examples. Paxillæ: more compact in some individuals, with a slight difference in width of paxillar area on rays, due to the variable width of superomarginals. Superomarginals: variable in width and number, being apparently slightly broader in Japanese specimens (but occasional examples, stations 3225 and 3258, from Alaska, also with broad plates); in number varying from thirty-three (Japanese) to forty-three (station 3258) in examples of same size (R, 70 mm.), the Japanese specimens consequently having longer plates. Inferomarginals: variable in width as superomarginals; covering either very compact and polygonal or more open and squamiform. Variations in adambulacral armature, mouth plates and actinal intermediate plates, sufficiently treated above.

Young.—The type described by Sladen is a small specimen. The smallest specimen in the collection from station 4792 has the following dimensions: R, 19 mm.; r, 8 mm. Superomarginals, twenty. The actinal interradial areas are small and lack enlarged spinules, as do the adambulacral plates on the proximal half of R. Terminal plate large, subglobose; proximal superomarginals with small bare spot; spinules of inferomarginals only a trifle enlarged beyond granules.

Type-locality.—"Christiansund" (Norway), 30 fathoms.

Distribution.—Off the eastern coast of the United States and Canada (lat. 44° 26′ to 37° 59′ N.) in 85 to 1,608 fathoms [Verrill, 1899]; off Norway (Christiania Fjord to Finmark, lat. 58° to 72° N.) eastward to the Murman coast; westward to the Shetland Islands, and Ireland [Ludwig, 1900]; Bering Sea (Bering Island; Pribilof Islands) extending at least as far as Kadiak Island in the eastern north Pacific, and south along the coast of Asia to the Sea of Japan, 70 to 351 fathoms.

Specimens examined.—Twenty-seven, from the following stations:

Specimens of Pseudarchaster parelii examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
3225	Near Unimak Island, Aleutians	85	black sand	1	U. S. Nat. Mus.
3257	do	81	gray sand, gravel	11	Do.
3258	do	70	black sand, gravel	2	Do.
3330	North of Unalaska Island, Aleutians	351	mud	1	Do.
3487	Bering Sea, west of Pribilof Islands	81	green mud, fine sand	1	Do.
3490	West of Pribilof Islands	78	do	1	Do.
3548	North of Unimak Island	91	black sand	1	Do.
3606	Bering Sea, north of Unalaska Island	87	green mud, fine sand	1	Do.
4287	Uyak Bay, Kadiak Island	66–67	gray mud	2	*Albatross*, 1903.
4291	Shelikof Strait, Alaska	65–48	blue mud, sand, gravel	1	Do.
4292	do	109–94	blue mud, fine sand	1	Do.
4784	Near Attu Island, Aleutians	135	coarse pebbles	1	*Albatross*, 1906.
4792	Near Bering Island	72	pebbles	1	Do.
4855	Matsushima, Sea of Japan	70–89	green mud	2	Do.

Remarks.—This species is variable in the Atlantic, and the Pacific specimens are certainly no exception to the rule. Greater differences are observable between specimens from station 3258 than between an example from off Newport, Rhode Island, and two from Norway, and a slightly larger one from 3257, near Unimak, Aleutian Islands. The specimens from Kadiak Island and Shelikof Strait are frankly not typical, but appear to be intergrades with *alascensis*. Japanese specimens are variable and not quite typical. The specimens from Matsushima, in proportion to length of ray, have fewer and hence longer marginals, which are wide. All the granulation is low, coarse, and very compact, and the adambulacral spinelets are very heavy in proportion to length, those on outer half of plate being granuliform. The wide marginals are duplicated in an Alaskan specimen from station 3258, there being also a more typical specimen from the same dredge haul. The enlarged actinal intermediate spinelets on both Alaskan and Japanese specimens (of which I have examined a number) are quite variable, sometimes being absent, while equal-sized examples have them. Postadambulacral fascioles are not always evident.

It appears as if this species, spreading south along the Alaskan coast, had changed into a form with narrower superomarginals, having less granuliform armature on the actinal surface, and less compactly placed granules on the abactinals. Along the Asiatic side the development has been toward fewer and broader superomarginals, with more compact abactinal granules, and an accentuation of the granuliform character of the actinal armature. The Japanese form has departed less from the type than has the British Columbian.

This species is the north Pacific and Atlantic representative of *Ps. discus* Sladen (from Messier Channel, between Chile and Wellington Island), to which it is closely related. It may be that *Ps. pulcher* Ludwig (Galapagos to southwest of Acapulco), founded on very small specimens, is the connecting link between the two forms.

A few words concerning the name adopted may be in order. In the Museum of Comparative Zoölogy are three specimens of "*Astropecten parelii*" from Norway, presented by Professor Sars in 1852. These agree very well with the original description and figures of Düben and Koren. There are no differences of importance between these specimens and an example of *Pseudarchaster intermedius* from off Rhode Island. Similarly, the Norwegian specimens belong to the same species as the Alaskan. There is far more difference among the various Alaskan examples than exists between these on the one hand and either the Norwegian or Rhode Island specimens on the other. The width of the paxillar area on the arm varies in this species, even in specimens from the same locality. It is not surprising, therefore, that the area is narrower in the specimens from Norway, just mentioned, than in the figure of Düben and Koren.[a] Düben and Koren figure also the superomarginal plates and paxillæ, the inferomarginals and adambulacral plates, and fortunately the tube feet. These have strong sucking disks. The figure is enough to place the animal in *Pseudarchaster*.

That *Astropecten parelii* and *Pseudarchaster intermedius* are one and the same (somewhat variable) species I have not the slightest doubt. I also doubt if *Pseudarchaster fallax* is anything more than a variety.

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[a] Plate 7, fig. 14.

Sladen placed *parelii* in *Tethyaster*, a subgenus of *Plutonaster*, while Bell, Norman, Grieg, and Ludwig relegated it to *Plutonaster*. Such a course is untenable, because *Plutonaster* belongs to a different family altogether, and has pointed tube feet, never sucking disks. This character alone is enough to exclude *parelii* from *Plutonaster*. As a matter of fact, *parelii* is so near the type of *Pseudarchaster* [that is, *discus*] that one is obliged to search carefully to find trenchant differences. The following are the considerations which lead one to rank *parelii* in *Pseudarchaster:* tube feet with sucking disks; character of the marginal plates, especially the inferomarginals; the characteristic adambulacral plates and armature, which is totally unlike *Plutonaster*; the actinal intermediate plates with spaced granules and incipient central spinule; the armature of the mouth plates, there being an unpaired median tooth directed over the actinostome; the presence of postadambulacral fascioles very characteristic of *Pseudarchaster* and never found in *Plutonaster* or allied genera.

In a specimen of *parelii* from the Copenhagen Museum: R = 43 mm., r = 14 mm.; superomarginals twenty-three; the superomarginals are considerably arched above the abactinal paxillar area on arms; the latter is narrower than the marginal plates, there being at the middle of ray only three longitudinal rows of paxillæ, and only a single row reaches terminal plate; about four and one-half to four paxillæ correspond to two superomarginals; furrow spinelets five or six; one or two actinal spinelets enlarged slightly; first row of actinal intermediate plates has incipient fascioles; a few of the actinal intermediate plates with slightly enlarged spinelets.

This specimen differs from the Alaskan chiefly in having tumid superomarginals and a narrower paxillar area on rays. There are about five transverse rows of of granules on the superomarginals (the same as in Alaskan specimens).

PSEUDARCHASTER PARELII ALASCENSIS Fisher.

Pl. 31, figs. 3–5; pl. 33, fig. 4; pl. 40, fig. 3; pl. 57, fig. 6.

Pseudarchaster alascensis FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 303.

Diagnosis.—Very close to *Ps. parelii*, and differing in having shorter and narrower superomarginals with less compact granules, less compact paxillar area, papilliform inferomarginal spinelets, more delicate and longer actinal intermediate, adambulacral, and mouth spinelets. The general facies of the two forms is different enough, but the actual differences, allowing for individual variation, are not great. R = 99 mm.; r = 34 mm. R = 2.9 r. Breadth of ray at base 40 mm.; at middle 15 mm.

Description.—Paxillæ are not markedly different from those of *parelii*, but are slightly spaced instead of crowded, and a trifle smaller, the central spinelets having convex instead of flat tips. The figures will give the best idea of this difference.

The superomarginal plates are decidedly narrower than in Japanese and most northern specimens of *parelii*. In these the widest plates in interbrachial arc are 9.5 mm. (R = 77 to 100 mm.) and in *alascensis* the same plates are 5.5 to 6 mm. (R = 73 to 99 mm.). In *alascensis* the granules are not close-set, forming a hard, smooth mail, but are spaced and those on outer edge of plate are enlarged, with strongly convex or conical subtubular tips. A specimen from station 4201 has these enlarged into small subconical spinules in the interbrachial arc.

The inferomarginal armature consists of slightly spaced subpapilliform slightly flattened spinelets with a transverse series of enlarged lanceolate appressed spinules.

Adambulacral plates with five or six tapering furrow spinelets compressed as in *parelii* but longer and more delicate, as are those of actinal surface. The figure will show the differences better.

The armature of the mouth plates is composed of terete or slightly compressed, tapering, rather slender spinelets, much longer than in *parelii*. The arrangement of spinules, however, is not materially different.

Spinelets of actinal intermediate plates are spaced and of a swollen papilliform shape. A number of plates bear an enlarged spinule, but these are usually scarce. Compared with a Japanese specimen of *parelii*, the spinelets are longer and less granuliform, and decidedly more spaced; the difference is not so obvious, however, when Alaskan specimens are used for comparison. Postadambulacral pectinate pedicellariæ present; but sometimes scarcely more than simple fascioles.

Type.—Cat. No. 22334, U.S.N.M.

Type-locality.—*Albatross* station 4236, near Yes Bay, Behm Canal, Alaska, in 147 to 205 fathoms, rocks, coarse sand.

Distribution.—Oregon to Queen Charlotte Sound and north, intergrading with *Ps. parelii* in the region of Kadiak Island.

Specimens examined.—Nine from the following localities:

Specimens of Pseudarchaster parelii alascensis examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
4201	Queen Charlotte Sound, off Fort Rupert, Vancouver Island, British Columbia.	107-68	rocks, coarse sand	3	*Albatross*, 1903.
4236	Vicinity of Yes Bay Behm Canal, Alaska	147-182	rocks, coarse sand	1	Do.
4251	Stephens Passage Alaska	198	rocky	1	Do.
4258	Vicinity of Funter Bay, Lynn Canal, Alaska	300-313	mud	2	Do.
2860	Off Queen Charlotte Island, British Columbia	876	green mud	1	U. S. Nat. Mus.
3788	Off Cape Blanco, Oregon[a]	1064	do	1	Do.

[a] Not typical.

Remarks.—Since describing this form in 1905 I have seen considerable material not then accessible, including specimens of *Ps. parelii* from the Atlantic and the Sea of Japan. The special characters of the present race are exhibited only by specimens from off British Columbia and southern Alaska, but examples from Kadiak and vicinity are intermediate, though a little nearer to *parelii*. It is impossible to assign them satisfactorily to either form.

That *Ps. pusillus*, from California, is not a dwarfed variety of this race, or of *parelii*, becomes very evident when equal-sized specimens are compared. A small specimen (R = 37 mm.) from station 4201 is nearer typical *parelii* than the adults; the paxillar and marginal granulation is more compact, and the adambulacral spinelets shorter. Compared with *pusillus*, this specimen has longer and narrower rays, very wide superomarginal plates, more crowded paxillæ (in view of their variation in *pusillus* the size is of no importance), much narrower paxillar area, less prominent inferomarginal spinules, much more compact inferomarginal and actinal intermediate spinulation, more numerous adambulacral spinelets, and especially lacks the prominent marginal fascioles of *pusillus*.

A very young specimen from station 2860, probably of this race (although in absence of adults from the same station it is not possible to be positive) has R = 7 mm., an arcuate pentagonal form, and a large naked area on each of the seven or eight superomarginals of the ray. The adambulacral plates have three or four furrow spinelets and the mouth plates an odd mouth spine. There are no enlarged inferomarginal spinules as in small specimens of *pusillus*.

PSEUDARCHASTER PUSILLUS Fisher.

Pl. 32, figs. 1–4; pl. 33, figs. 1, 2; pl. 57, figs. 4, 4*a*; pl. 59, fig. 4.

Pseudarchaster pusillus FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 304.

Diagnosis.—Rays 5. R = 32 mm.; r = 14.5 mm.; R = 2.2 r. Breadth of ray at base, 17.5 mm. A variation with shorter rays: R = 1.8 r. Rays short and broad at base; interbrachial ares very wide and rounded; abactinal surface subplane to slightly arched. Paxillæ spaced and small or large and more closely placed; very variable; papulæ conspicuous, extending 0.7 to 0.8 length of ray; abactinal plates strongly lobed. Marginal plates conspicuous, the inferomarginals with a widely spaced subpapilliform granulation and a median transverse row of four prominent sharp spinules which are reduced to two on outer half of ray. Superomarginals with three to five transverse rows of spaced granules one to three enlarged into subtubercular granules on outer end of plate; inferomarginal spine on outer end of plate very prominent in young specimens. Adambulacral plates angular, with palmate furrow series of four or five terete blunt spinelets, and on actinal surface a semicircle of unequal "barley-corn" spinelets on border of plate surrounding a similar but enlarged central spinule. Sometimes pectinate pedicellariæ present on furrow between adambulacral plates, and on some of actinal intermediate plates near mouth plates. Mouth plates with prominent median tooth at inner angle, and an angular marginal series of unequal spinelets. Actinal interradial areas extensive but plates not encroaching far on ray; plates with "barley-corn" spinelets and frequently an enlarged spinule. Superambulacral plates present.

Description.—The variable shape of this species is noted under "Variations." Paxillæ usually small and spaced but extremely variable in size; arranged in regular series parallel with median radial, except over center of disk where there is no regular arrangement. Paxillæ also form transverse oblique series and decrease in size toward marginal plates and center of disk. Paxillæ of type (and of specimens from hard bottom) have three to five robust, but small, clavate or pestle-shaped granules, alternating with or surrounded by a regular series of six to ten, or slightly more, slenderer spinelets or granules. Small lateral paxillæ with only three to six spinelets. An extreme variant from type (station 4367) has large rather closely placed paxillæ with a convex crown of upwards to fifteen central low polygonal or roundish granules, surrounded by numerous slender spinelets in a peripheral series. About three transverse rows of paxillæ, in this specimen, stand opposite two superomarginals (four in type). Only one series of paxillæ reaches terminal plate, but the two adradial very nearly. In typical specimens papulæ are readily seen between paxillæ, generally six about each.

Dorsal plates or bases of paxillæ are distinctly and often very conspicuously lobed on the proximal radial regions. At tip of ray beyond the papular area the plates become hexagonal or elliptical; along margins of area they lose the lobes, and vary greatly in shape, even becoming triangular; on center of disk the plates are without well-defined lobes and are irregular. On the proximal radial areas there are six lobes to a plate, the plates overlapping by them. These lobes vary greatly in length, being longest and slenderest on typical forms with small paxillæ. Papulæ extend along ray nearly to tip (0.7 to 0.8 length measured on side); elsewhere they are generally distributed except where interradial septum joins abactinal surface.

Marginal plates well developed. Superomarginals, about twenty-five in number from median interradial line to extremity of ray, form a steep, arched bevel to border. Plates wider than long, the width decreasing gradually along ray. They are covered with spaced, low, hexagonal, or roundish, convex-tipped granules forming two or three transverse series, with an additional series of smaller, slenderer, often pinched granules on either transverse margin. The larger median granules increase in size toward outer and lower margin of plate near which are one to three enlarged subtubercular granules.

Inferomarginals correspond to superomarginals in position, and form a similar bevel to actinal surface. They are covered with a spaced papilliform granulation, and a median transverse row of four prominent sharp spinules, which are reduced to two on outer half of ray. Narrow fasciolar channels run transversely between the plates of both series. When denuded of granules the specialized ridges of marginals are seen to be much thicker than intervening channels. Terminal plate ovoid and prominent, the narrower end toward paxillar area. Young specimens have two prominent tubercles at tip, on either side.

Adambulacral plates with an angular furrow margin; of this the side toward mouth is shorter than the aboral; or the margin may appear, superficially, to be curved. Plates wider than long. Armature consists of (1) a palmate furrow series of four or five cylindrical or slightly compressed, slightly tapering, blunt-tipped spinelets, sometimes swollen and subpapilliform. Rarely there are six or as few as three. (2) On actinal surface is a semicircle of unequal, very small, swollen papilliform spinelets on border of plate, surrounding a similar but enlarged, often curved, central spinule. The outer plates of the series frequently have the spinelets arranged in two rows, and there are two enlarged spinules; or these spinelets may be arranged in a circle around the enlarged spinule, which increases in prominence toward tip of ray.

Mouth plates prominent actinally, and the combined pair with a broadly oval contour, the wider end toward actinostome. Armature of margin consists of a prominent median (unpaired) spine, slightly flattened, and on each plate an angular series rising toward peristome very slightly. This series consists of two or three spinelets on margin toward actinostome and about four or five on the furrow margin, each series being graduated in size toward the angle, where there is usually one very small spinelet. This marginal angle is nearer the inner than the outer or aboral end of free margin. On actinal surface is a superficial series of seven or eight terete blunt spinelets bordering the suture and on the adambulacral margin four or five continuing the furrow series, both decreasing in size toward the outer end of plate. A spinelet of latter series sometimes becomes enlarged and stands midway between the two series, forming an actinal spinule homologous with that of the adambulacral.

Actinal interradial areas fairly large, but plates extending only one-third length of ray measured alongside, or one-half measured from center of disk. Plates arranged in series extending from adambulacrals to inferomarginals, and covered with comparatively few, spaced, swollen, small spinelets usually forming a circle surrounding an enlarged central spinule. These spinelets have a narrow proximal and a swollen pointed distal portion, and resemble the so-called "barleycorn" spinelets of many Astropectinidæ. When dry these spinelets become very slightly slenderer, but retain the characteristic form.

The channels running interradially between the series of intermediate plates form undifferentiated fascioles. A small percentage of the specimens have pectinate pedicellariæ or fascioles on the actinal intermediate area or between the adambulacral plates. In the latter case a comb of about four spinelets on each plate bend over the transverse suture and meet spinelets of an adjacent plate. This is simply the "postadambulacral fasciole" transferred to the adambulacral plates. The actinal intermediate pectinate pedicellariæ occur mostly over the transverse sutures between proximal plates of the series adjacent to adambulacrals. Three to five somewhat enlarged, slightly flattened spinelets with truncate or rounded often slightly flaring tips compose each comb. There is considerable variation in the amount of specialization or differentiation undergone by the spinelets. Some are considerably flattened, especially in the case of the adambulacral pedicellariæ. An interradial pedicellaria just back of mouth plates, and one on either side is of fairly frequent occurrence. Rarely a small pedicellaria is found between these and marginal plates.

Madreporic body fairly conspicuous, situated midway between center and inner edge of superomarginals; edges overhung by seven to ten paxillæ; outline variable; striations irregular centrifugal.

Color in life: Abactinal surface dull coral red, rather deep, varying to maroon in small specimens, in which case the abactinal paxillar area is much darker than marginal plates, which are bright coral red; actinal surface of inferomarginal plates pinkish buff; actinal intermediate areas grayish, often tinged with pink; tube feet olive buff to raw sienna. A second phase is of the same general tint, but much paler.

Anatomical notes.—Superambulacral plates present but poorly developed, and absent from first two ambulacral ossicles; rudimentary or lacking beyond middle of ray. Gonads forming a single tuft at either side of interradial septum. Anal opening present, small. Intestinal cœcum divided into two parts, each of which has three or four irregular branches with a few small pocket-like subdivisions. One Polian vesicle in each interradius. Tube feet with well-developed sucking disks; no deposits in walls.

Variations.—This is a variable species both in respect to shape and details of ornamentation, particularly in the size of paxillæ. The last variation seems to be correlated with the character of the bottom.

The extremes in body form are best appreciated from the photographic figures, and range from a short broad-rayed almost arcuate-pentagonal shape (which is unusual) to one with smaller disk and longer, distally attenuate rays. The following table will give an idea of the differences:

Table showing variations in Pseudarchaster pusillus.

Station.	R.	r.	R : r.	Breadth of ray at base.	Number of superomarginals.
4423	29	16.0	1.8 : 1	18.0	20
4368	28	14.0	2 : 1	17.0	21
4423	32	14.5	2.2 : 1	17.5	25
3191	44	18.0	2.44 : 1	20.0	30

Next to the shape the size of paxillæ is most noticeable in variability. The extremes have been noted in the foregoing description. Specimens with small spaced paxillæ are from hard sandy bottom; those with larger and more closely placed paxillæ (as, for instance, the specimen mentioned from station 4367) are from soft mud. The large paxillæ evidently are a protective device for the papulæ, preventing their being clogged with mud. The danger of such an event is very slight on hard sand or shells; hence the partial atrophy of the paxillar crown in specimens from such a substratum. Unfortunately the type is not so typical in regard to paxillæ as the variety with more closely placed and slightly larger ones. The specimen from station 4367 is extreme. (See figures.)

There is variation in the width of superomarginals, and in the degree in which they encroach on paxillar area. This gives a slightly different appearance to abactinal paxillar area. Small variation occurs in the number of transverse rows of granules, as well as in the length of inferomarginal spinules. Variations in occurrence of pedicellariæ and in adambulacral armature have already been mentioned in the description.

Young.—Numerous very small specimens from stations 4433 and 4533 are easily recognizable as *Pseudarchaster.* R = 5 mm. Paxillæ have one to four spinelets; superomarginals seven; terminal plate large with two spinelets; one very prominent inferomarginal spine, forming longitudinal series all along ray; adambulacral plates with three furrow and two to four much shorter actinal spinelets; the median unpaired tooth of mouth plates very prominent. The conspicuous inferomarginal spine with several associated spinules projecting out from side of ray is very characteristic.

Type.—Cat. No. 22335, U.S.N.M.

Type-locality.—*Albatross* station 4423, between Santa Barbara and San Nicholas Island, California, 216 to 339 fathoms, shells, black pebbles, green sand.

Distribution.—North of Monterey Bay, California, to Los Coronados Islands, Lower California, and from 54 to 382 fathoms.

Specimens examined.—Four hundred and sixty-one, from the following stations:

Specimens of Pseudarchaster pusillus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2892	Santa Barbara Channel, California	284	yellow mud	57	U. S. Nat. Mus.
2909[a]	Off Point Conception, California	205	green mud	272	Do.
2948	South of Santa Cruz Island, California.	266	gray sand, gravel, broken shells	2	Do.
3105	Off Half Moon Bay, California	217	fine gray sand	1	Do.
3187	Off Point Sur, California	298	yellow sand	11	Do.
3189	South of Point Sur, California	218	mud	3	Do.
3191	do	211	brown mud	47	Do.
3200	Santa Barbara Channel, California	265	green mud	5	Do.
3202	Monterey Bay, California	382	do	2	Do.
3669	Off Monterey Bay, California	278	green mud, fine sand	4	Do.
4339	Vicinity of Los Coronados Islands, Lower California.	241–369	green mud	1	*Albatross*, 1904.
4359	Near San Diego, California	191–98	gray sand, green mud	1	Do.
4367	do	181–215	green mud	1	Do.
4368	do	215–240	do	3	Do.
4423	Between Santa Barbara and San Nicholas Island, California.	216–339	shells, black pebbles, green sand	3	Do.
4430	Near Santa Cruz Island, California	197–281	black sand, pebbles	1	Do.
4433	do	270–243	green mud	13	Do.
4533	Monterey Bay, California	293–194	green mud, sand	32	Do.
4535	do	71–54	very hard sand	1	Do.
4542	do	677–236	hard	1	Do.

[a] The majority of these specimens are from 2909. The contents of more than one bottle are represented, however. Several were broken together during the California earthquake of 1906, and the above label was in the remains of one bottle.

Remarks.—This species resembles *Ps. verrilli* Ludwig[b] in several ways, but differs in lacking the independent connecting plates on the papular areas of dorsal skeleton, as well as in having true pectinate actinal intermediate and interadambulacral pedicellariæ (when any pedicellariæ are present), in having inferomarginal spinules, and enlarged superomarginal granules on outer end of plate, a different adambulacral armature and a prominent unpaired tooth at inner angle of mouth plates. Ludwig's *Ps. pulcher*[c] appears to be closely related to *pusillus*, but the papulæ are not so restricted in the latter, and the absence of marginal spinules, particularly in the young, as well as the absence of an enlarged unpaired tooth are sufficient to separate it. Other differences exist in details of structure.

Ps. pusillus differs from *Ps. parelii* in having shorter, broader rays, broader paxillar area on rays, less compact paxillæ, less compact and more hemispherical superomarginal granules, much more prominent inferomarginal spinules, especially in young, less densely granulated actinal intermediate plates, less numerous furrow and actinal adambulacral spinelets. The general facies of the two species is very different.

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[b] Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 116. (Gulf of Panama).

[c] Idem, p. 110.

PSEUDARCHASTER DISSONUS Fisher.

Pl. 34, figs. 1–3; pl. 57, figs. 7, 7*a*.

Pseudarchaster dissonus Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 551.

Diagnosis.—Closely related to *Ps. pectinifer* Ludwig, but differs in having actinal bivalved pedicellariæ of a highly characteristic form, coarser granules to abactinal paxillæ and superomarginal plates, proximally smaller adambulacral plates, fewer actinal adambulacral spinelets, and pointed furrow spines. R = 170 mm.; r = 61 mm.; R = 2.6 r. Breadth of ray at interradial line, 72 mm.; at one-third R from center, 50 mm.; at two-thirds R, 24 mm. Interbrachial arcs wide and rounded; rays tapering, with straight sides, pointed; abactinal area sunken on interradii and capable of inflation. Abactinal paxillæ large, with fifteen to twenty-five central, and about the same number of slender peripheral granules; abactinal plates subcircular. Marginal plates narrow, tumid, the two series difficult to differentiate; covered with thickened papilliform spinelets or elongate granules on upper series and spinelets on lower; two to four or five enlarged spinules on inferomarginals. Adambulacral plates longer than broad, with very acute furrow margin bearing six to eight spinelets, and on actinal surface three to five slender spinelets and one or two enlarged sharp spinules; all spinelets sheathed in membrane. Actinal intermediate areas very extensive; plates covered with slender, skin-sheathed spinelets; each plate with one, sometimes two, enlarged spinules, all directed toward margin. On basal third of ray, valvate pedicellariæ on transverse sutures between first longitudinal row of actinal intermediate plates; or valvate pectinate. Well-developed superambulacral ossicles, lodged in membranous septa running from ambulacrals to inferomarginals.

Description.—Paxillæ large; largest on proximal radial areas, decreasing in size toward marginal plates and radially toward extremity of ray; in giant specimen less obviously toward center of disk. Paxillar crowns hexagonal; pedicel of paxilla broad and low, widening at summit; this tabulum, in large paxillæ, covered with fifteen to twenty-five central slightly spaced, roundish or subhexagonal flat-topped granules, quite robust, and variable in shape, but usually low and subcylindrical, and a peripheral series of fifteen to twenty-five slenderer peripheral granules. Toward margin the spinelets are much fewer and form a convex more compact group. Three longitudinal series touch terminal plate.

Abactinal plates subcircular, arranged in longitudinal series parallel with the radial, except on center of disk and extreme margin of area, where there is no regular arrangement. On the latter area the plates are often more or less elongate longitudinally and in median radial area there are slight indications of lobing. Papulæ single, and six about each plate. They are distributed all over the abactinal area except for about 8 mm. at tip of ray.

Superomarginal plates, fifty-six to a ray, are relatively small, and do not encroach conspicuously on abactinal area. Each plate is distinctly tumid when the spinelets are cleaned off. Sutural lines very indistinct, it being impossible to distinguish the suture between the two marginal series without first cleaning plates. (In slightly smaller specimen (station 3788) this line can be seen readily.) The two series of plates together form a rounded margin to ray. Plates covered with thickened papilliform granules or stumpy spinelets, like those on adjacent paxillæ, these increasing in length toward lower edge and passing without break into spinelets of inferomarginals. On proximal third of ray two or three spinelets near lower end of plate are enlarged into more robust clavate spinules, which in interbrachial arc form a transverse row, or a group with several spinelets of intermediate size. All are incased in membranous sheaths.

Inferomarginals opposite superomarginals and encroach much more on actinal area than do superomarginals on abactinal. They are likewise tumid and are covered with rather slender papilliform spinelets (thickly cased with membrane), which may become subsquamiform. Enlarged flattened lanceolate spinules form an irregular transverse series of four or five, or there may be an oblique series of two or three near inner end of plate, and a longitudinal series or group of several only slightly enlarged spinelets at upper end of plate. The spinelets are packed together and rather difficult to diagnose, inasmuch as they vary in length and intergrade with the enlarged spinules. Terminal plate small, apparently granular, and ovoid in shape.

Adambulacral plates with an acute furrow angle projecting conspicuously between adjacent tube feet. These projections are rather widely spaced owing to the length of the plates. Armature spiniform, not granuliform. It is difficult to diagnose exactly the armature owing to slight variations. On the very angular margin are five to eight fairly slender tapering spinelets, with membranous covering, which cause them to appear flattened and blunt. The median, on the apex of angle, is usually slightly longer than rest. On actinal surface are two to five delicate spinelets and usually one or two enlarged sharp spinules sheathed in membrane. Of the latter there is usually but one at base of ray, and two distally, where they are more prominent. A peculiarity of the plates is the fact that at base of ray they are so spaced that an intermediate plate may border the furrow for a short distance, and two or three actinal intermediate spinelets may stand in between two consecutive furrow series. Very soon, however, the plates come close enough together to have transverse sutures.

Actinal interradial areas large, paved with rather small superficially oblong, squarish, or even nearly round plates arranged in series running from adambulacral to margin. Internally the plates imbricate, and are broadly irregular oval in form. On the ray the plates also form longitudinal series, one extending about 0.8 length of ray, a second over 0.6, a third about 0.5. On the basal half the longitudinal series are not distinct except the two or three adjacent to furrow. The plates are armed with slender spaced spinelets directed toward margin. These are slightly clavate or are terete, vary in length, and are normally sheathed in membrane, which may become thickened at end, obscuring sharp or blunt tips. One or two enlarged, more robust spinules stand on each plate. Very narrow, shallow channels separate the consecutive interradial or transverse series of plates.

On the basal third of ray, on the transverse suture separating consecutive actinal intermediate plates of the series adjacent to adambulacrals is a valvate pedicellaria with jaws about twice as long as high. Each jaw is on a separate plate and they meet above the suture, being usually close to the furrow margin, and opposite a suture between two adambulacrals. They are confined to the proximal third of R, and are modifications of the ordinary postadambulacral fascioles. In *Ps. pectinifer* the spinelets of these are prominent and show a tendency to become flattened. In *dissonus* the flattening is probably aided by a coalescence of spinelets, and the result is a pedicellaria essentially like that of the typical Goniasteridæ, except for the fact that the jaws stand on separate plates. The simplest postadambulacral fascioles are thus incipient pedicellariæ. The figures will, perhaps, show the exact form better than further description.

Combined mouth plates elliptical, slightly convex, broadest at about the middle, and of the same general appearance as those of *pectinifer*. Besides the large median unpaired blunt tooth are nine or ten slightly sharpened marginal spines. The actinal surface is armed with numerous slender spinelets and one or two enlarged spinules. (See description below of a smaller specimen.)

Madreporic body small, situated 0.4 minor radius from center. Striations deep and radiating. It is partly overhung by paxillæ.

Anatomical notes.—Superambulacral plates well developed beyond eighth to eleventh ambulacral ossicle. The first is on the fourth or fifth. The first plate meeting an inferomarginal is on eighth to eleventh ambulacrals. The superambulacrals are lodged in a sort of laminar septum, with an upper free edge, extending between the ambulacral ossicles and the inferomarginals. In this low septum the plate is firmly held. It is more in the form of a lamina than a rod. In the big specimen, and to a less extent in the smaller ones, the superambulacral ossicles appear to be jointed, probably due to artificial fractures partly healed, or possibly permanent, owing to the unusual length of the plate. For instance, in the type as far along the ray as there are two longitudinal series of intermediate plates these fractures occur, and proximally there may be two in the length of a single plate. In *Ps. pectinifer* the same tendency is observable, though not so marked. Over the distal region with one row of actinal intermediate plates the superambulacrals are quite short, and become rudimentary, then cease a short distance beyond the last intermediate plate. Gonads in a single tuft on either side of interradial septum. Tube feet with a prominent sucking disk; no deposits. Anus present.

Notes on an immature specimen.—A specimen from station 3601 has been referred to this species on the evidence of the peculiar pedicellariæ, adambulacral armature, and superambulacral plates. Superficially it presents a number of points of difference, which are probably due to age and the greater depth.

R = 52 mm.; r = 20 mm.; R = 2.6 r. Rays narrow distally. Paxillæ conspicuously smaller on center of disk and on interradial areas than on radial areas; the latter with ten or eleven central granules and twelve to fifteen smaller compressed peripheral ones. Marginal plates not encroaching much on either area, as in type, but the covering rather more granuliform. Adambulacral plates, as in type—narrow, with a very prominent furrow angle; about six furrow spinelets, but as few as three on a few proximal plates. Mouth plates prominent actinally, the pair with an ovoid form. On the broad inner truncately rounded end of combined plates a series of seven spinelets, slightly flattened and bluntly pointed, is graduated on either side from the median unpaired spine—there being thus three spinelets to each plate; on edge toward mouth of furrow are three or four smaller stumpy spinelets graduated either way from the central. After an interval this series is continued along margin adjacent to first adambulacral in five or six small papilliform spinelets. About eight to ten spinelets stand on edge of median suture and five or six, one of which may be enlarged, form an intermediate series.

The postadambulacral pedicellariæ or fascioles are somewhat different from those of type, and are intermediate in some respects between the latter and the ordinary form. They extend about a third the length of furrow. At the base of the series each consists of two or three flattened low jaws on either plate, forming a sort of compound pedicellaria. One pedicellaria has a single long jaw on one plate and opposing it two jaws, the whole occupying the entire width of the intermediate plate. At the distal end of the series the pedicellariæ are single and like those of type. It seems probable that as growth proceeds two opposing jaws develop, while the others atrophy. The figures will give a better idea of these pedicellariæ than a description will. (Pl. 57, fig. 7*a*.)

The intermediate plates are armed with short papilliform spinelets, not so long nor so slender as in type. There is usually one enlarged spinelet to each plate on the disk. Papulæ extend 0.6 length of R on radial area; not so far on sides, and are lacking in a triangular interradial space.

Young.—A specimen with R = 28 mm. is doubtfully referred to this species. It has not yet developed the characteristic pedicellariæ. The character of the spinulation, armature of mouth plates and of adambulacral plates has led to the supposition that the specimen belongs here.

Type.—Cat. No. 27882, U.S.N.M.

Type-locality.—*Albatross* station 3346, off Oregon, 786 fathoms, green mud.

Distribution.—Bering Sea to Oregon, 786 to 1,064 fathoms.

Specimens examined.—Five: the type; an immature specimen from station 3601, Bering Sea, between St. George Island and the Bogoslof Islands, 1,044 fathoms, green mud, fine sand; a young specimen doubtfully referred to this species, station 3075, off Sea Lion Rock, Washington, 859 fathoms, green mud; two specimens from station 3788, off Cape Blanco, Oregon, 1,064 fathoms, green mud.

Remarks.—This species is characterized by postambulacral fascioles of a bivalved form, which may consist, however, of multiple opposing jaws, and by the details of abactinal, marginal, and adambulacral armature, as noted below in the comparison with *Ps. pectinifer,* to which it is closely related.

I have two specimens of *Ps. pectinifer* Ludwig[a] from station 2807, Galapagos Islands, 812 fathoms, globigerina ooze, coral mud. It is very evident that *dissonus* bears the closest sort of relationship with *pectinifer* and probably has a continuous distribution with it. No specimens of an intermediate character or from intermediate localities are at hand however.

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[a] Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 106, pl. 7, figs. 34, 35.

The following apparently constant differences separate the north Pacific species from *pectinifer*, the larger specimen of which has R = 95 mm. (the same as Ludwig's type from the Gulf of Panama):

pectinifer.	*dissonus.*
Granules of central portion of tabulum only half as broad as those in an equal-sized specimen of *dissonus*.	Notably larger granules to the abactinal paxillæ, and fewer on surface of tabulum.
Superomarginal plates at base of ray twice as wide as long; granulation of even length, or only one or two slightly enlarged granules near outer end of plate; granules very short, truncate, or slightly convex at tip.	Superomarginals at most one and one-half times as wide as long; outer granules conspicuously longer than inner, and one or more in the form of short spinelets shaped something like a grain of wheat; other granules much fewer than in *pectinifer*, and more or less elongate.
Inferomarginal spinelets slenderer and more numerous.	Inferomarginal spinelets coarser and fewer.
Actinal intermediate spinules slenderer and longer.	Actinal intermediate spinules shorter and stouter.
Postadambulacral pedicellariæ pectinate only.	Postadambulacral pedicellariæ bivalved, but with sometimes a valvate pectinate form.
Adambulacral plates proximally as wide or wider than long, with truncate or blunt untapered furrow spinelets; numerous actinal spinelets; intermediate plates and pedicellariæ normally placed, not encroaching upon adambulacrals and furrow margin.	Adambulacral plates proximally much longer than wide, with tapering sharp furrow spinelets; few actinal spinelets; intermediate plates and their pedicellariæ (proximally) encroach upon adambulacrals and sometimes push between them and border the furrow.

In *pectinifer* the adambulacrals are joined by their transverse margins, which are well marked; but in *dissonus*, as shown in the figures, there may be no true lateral sutures between the plates, as the first row of intermediate plates encroaches upon them. A portion of the inner edge of an intermediate thus comes to border the furrow between two adjacent but partially separated adambulacrals. There is no hint of this in *pectinifer*, the surface of whose adambulacrals is much more spacious and spiny.

Subfamily GONIASTERINÆ Verrill, 1899 (extended).

Goniasterinæ+*Mediasterinæ* Verrill, Trans. Conn. Acad., vol. 10, 1899, p. 200.

Pentagonasterinæ Sladen, *Challenger* Asteroidea, pp. xxxi, 262, 264.—Perrier, 1894, p. 337.

Genus MEDIASTER Stimpson.

Mediaster Stimpson, Boston Journ. Nat. Hist., vol. 6, 1857, p. 530. Type, *M. æqualis* Stimpson.—Sladen, *Challenger* Asteroidea, 1889, p. 263.—Perrier, Expéd. sci. du *Travailleur* et du *Talisman*, 1894, p. 377; Résult. camp. sci. du Prince de Monaco, fasc. 11, 1896, p. 45.—Verrill, Trans. Conn. Acad., vol. 10, 1899, p. 178.

Isaster Verrill (not of Desor), Proc. U. S. Nat. Mus., vol. 17, 1894, p. 257. Type, *Archaster bairdii* Verrill.

Pentagonaster Sladen (not Gray) part, *Challenger* Asteroidea, 1889, p. 277.

Diagnosis.—Goniasteridæ having a stellate form, with a broad flat disk, wide interbrachial arcs and evenly tapered rays; with tabulate, regular more or less paxilliform abactinal plates which meet the terminal plate in from one to three longitudinal series; with internal radiating ossicles connecting the abactinal plates of papular areas; papulæ single or grouped in twos or threes; marginal plates commonly not tumid; actinal interradial areas extensive; adambulacral plates with straight furrow margin bearing three to eight rather slender, often prismatic spinelets, the actinal surface with a rosette or double row of shorter spinelets which may be angular and obtuse, and toward tips of rays some of them may become larger and longer. Some of these spinelets may be replaced by spinuliform or clavate, two- or three-bladed pedicellariæ. No odd median mouth spine as in *Pseudarchaster*. Abactinal and marginal pedicellariæ, low valvate foraminate; actinal intermediate pedicellariæ like the abactinal, or with slender spatulate jaws. *Rudimentary superambulacral plates present.*

Remarks.—This genus is closely related to *Ceramaster*, as here limited, but differs in having internal radiating ossicles connecting the slightly lobed well-spaced abactinal plates, and in possessing also rudimentary superambulacral plates. These two characters will also separate *Mediaster* from *Nymphaster* and *Nereidaster* both of which I have examined with reference to these features. The analytical key will serve to contrast the present genus with others more distantly allied. The *Nectria* of Gray which bears a certain resemblance to *Mediaster* is probably not so close as the abactinal surface would lead one to expect. There are intermarginal papulæ, superambulacral plates, and sometimes pincer-shaped pedicellariæ. with several jaws.

The first adequate account of this genus was given by Verrill (1899) who ranked in it the following forms: *M. æqualis* Stimpson, *M. bairdii* Verrill (olim *Isaster*), *M. agassizii* Verrill, *M. pedicellaris* Perrier (olim *Goniodiscus*), *M. arcuatus* (Sladen), *M. japonicus* (Sladen) *M. patagonicus* (Sladen). The last three species were described under *Pentagonaster* by Sladen. A very important feature of the genus, the rudimentary but constantly present superambulacral plates, was overlooked by Verrill, who was the first to discover the internal abactinal ossicles. The three species of Sladen I have since examined with special reference to the presence of the internal ossicles and superambulacral plates, as these forms were not accessible to Verrill. *Arcuatus* is a *Mediaster*, but *patagonicus* and *japonicus* lack the diagnostic characters of the genus, and fall within the limits of *Ceramaster*. Both *pedicellaris* and *agassizii* have not been dissected so that they must still remain questionable members of the genus, as also *M. florifer* (Alcock). It is impossible to identify a *Mediaster* from an external examination only. The following species belong to *Mediaster* as here defined: *æqualis* Stimpson, *bairdii* (Verrill), including *stellatus* Perrier, *arcuatus* (Sladen), *tenellus* Fisher, *transfuga* Ludwig, *ornatus* Fisher. The additional problematical species are: *pedicellaris*, *agassizii*, and *florifer*. *Mediaster elegans* Ludwig (1905) lacks the diagnostic features of the genus; there is no advantage in placing it in the present group.

KEY TO THE SPECIES OF MEDIASTER HEREIN DESCRIBED.

Papulæ grouped in twos and threes; pedicellariæ bivalved, longer than high; pedicellariæ of actinal interradial areas like those of the abactinal surface; adambulacral spinelets rather robust and prismatic.. *æqualis*, p. 198.

Papulæ single; pedicellariæ broadly spatulate, slightly higher than wide, those of actinal interradial areas with long slender jaws, unlike the abactinal; furrow spinelets long, compressed, rather delicate.. *tenellus*, p. 202.

MEDIASTER ÆQUALIS Stimpson.

Pl. 35, figs. 1–3; pl. 59, figs. 1, 1*a–c*.

Mediaster æqualis STIMPSON, Boston Journ. Nat. Hist., vol. 6, 1857, p. 530, pl. 23, figs. 7–11.—J. F. WHITEAVES, Trans. Roy. Soc. Canada, vol. 4, sec. 4, 1886 (1887), p. 117 (Malcolm Island, Queen Charlotte Sound, British Columbia).—SLADEN, *Challenger* Asteroidea, 1889, p. 572.—VERRILL, Trans. Conn. Acad., vol. 10, 1899, p. 179, pl. 24, figs. 10–12.

Description.—Rays five. $R^a=84$ mm.; $r=32$ mm.; $R=2.6r$. Breadth of ray at base, 36 mm. $R^b=56$ mm.; $r=22$ mm.; $R=1.54$ r. Breadth of ray at base, 26 mm. Interbrachial arcs wide, rounded or subangular; rays regularly tapering, rather slender toward tip, blunt. Marginal plates conspicuous, but as a rule not encroaching much on abactinal area; sides of body rather evenly rounded. Superomarginals, twenty-eight to a ray (in a specimen with $R=84$ mm.), almost plane to slightly tumid, wider than long, covered with many small pentagonal to roundish, close set, but nevertheless distinctly spaced, flat-topped granules, of which the marginal series is larger, and transversely oblong; a plate here and there may bear a typical low bivalved pedicellaria with two or three jaws, these not extending above the level of the granulation, but with a base four or five times as wide as height of jaw. Inferomarginals similar to superomarginals, the suture between the two series being more or less zigzag.

Abactinal surface usually slightly convex, covered with large tabulate plates or parapaxillæ well spaced as a rule, and bearing a flat-topped ornate crown of upwards to twenty-four central, trapeziform, pentagonal, or more rarely roundish, truncate or convex slightly spaced granules, and upwards to 25 slightly longer peripheral granules, with an upper face four-sided and beveled inward; frequently some of the granules are replaced by a large low bivalved pedicellaria; median radial row of plates attain the terminal plate and the adradials frequently, but not always. Papular areas extensive; papulæ two or three in a cluster, about six clusters around a plate; lacking at tip of ray and from a small triangular interradial area near margin; abactinal plates roundish, with six short lobes, well spaced (except off the papular regions), and connected by small independent internal radiating ossicles, six to a plate.

Actinal interradial areas extensive, the intermediate plates extending nearly to tip of ray; they are close set, broadly ovate, slightly imbricated and bear roundish, rhombic, or elliptical groups of two or three central (also one or none) and five to ten peripheral prismatic, elongated or spiniform granules. A few plates especially near furrow, bear a good-sized bivalved pedicellaria with two, three, or four jaws, sometimes higher and not so long at the base, as abactinal pedicellariæ.

Adambulacral plates squarish, not large, with a furrow series of three to five, oblong, more or less prismatic or compressed blunt spinelets, subequal in size; external to these, two successively shorter series form a rosette-like group, those nearest the furrow series being thicker than the latter, prismatic, or quadrate in section and about three in number; the outermost series usually has four or five granules like those of adjacent intermediate plates; occasionally on the outer half of ray an adoral spinelet of the inner series is replaced by a pedicellaria with two or three

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[a] Example from *Albatross* station 4228—S. E. Alaska.

[b] Example from *Albatross* station 3159—off Point Reyes, California.

short, stout, truncate, slightly tapering, spiniform jaws. On the distal part of the ray one or two of the spinelets on the central part of the plate become considerably longer and thicker than the rest.

Mouth plates, rather small and not prominent actinally, with a furrow series of five to seven prismatic compressed spinelets (the innermost largest and most compressed) and a parallel actinal series of three to five thicker prismatic spinelets all similar to but larger than the adambulacral spinelets; outer part of plates with granules.

Color in life, abactinal surface deep brilliant poppy red to vermilion; actinal surface "salmon" orange; tube feet scarlet with sucking disks of flesh color.

Anatomical notes.—Abactinal plates, when viewed from the inner surface, are rather small and roundish with short blunt lobes, widely separated in fully grown specimens, and connected by radiating independent ossicles. (See fig. 1, pl. 59.) These ossicles leave triangular papular spaces in which two or three papulæ commonly occur. The papular area is very extensive, comprising practically all the abactinal surface except the very restricted interradial areas (where the plates are close together and lack ossicles) and a small space at the tip of ray. The papular area is more extensive, especially interradially, than in *M. bairdii*, *M. ornatus*, or *M. arcuatus*, all of which possess the internal radiating ossicles.

I was considerably surprised to find rudimentary superambulacral plates in this species. *Mediaster bairdii*, *M. arcuatus*, and *M. ornatus* were examined and found to possess them also. *Ceramaster* lacks any trace of the plates, as does also *Nymphaster ternalis* and *Nereidaster bowersi*. I think it probable that all species of *Mediaster* have rudimentary superambulacrals. In *M. æqualis* they begin with the second ambulacral ossicle and extend far along ray, or until the lower end of ambulacral ossicles touch the inferomarginals. The plates are small and oval in form (Pl. 59, fig. 1*c*), are entirely covered by connective tissue, so that the skeleton must be treated with caustic potash before they can be seen. In *M. arcuatus* (Sladen), *M. bairdii* (Verrill), and *M. ornatus* Fisher the ossicles do not begin so near the mouth, but start at varying distances therefrom, and die out under the same conditions as in *æqualis*. In *M. arcuatus* the plates are slender and longer than in any other species.

The actinal intermediate plates, from the internal view, are broadly oval and slightly imbricated.

Intestinal cœcum consisting of five irregular, unequal, sparsely lobed divisions, the longest reaching to margin; no central portion, the divisions meeting at the intestine; anus present; hepatic cœca long; stomach small. Gonad in three tufts on either side of the uncalcified interradial septa. Tube feet with sucking disks.

Variations.—When compared with specimens from Chignik Bay, Alaskan Peninsula, Southern Californian examples present no greater differences than such as result from individual variation. Northern specimens appear to be better supplied with pedicellariæ, especially on the distal adambulacral plates, but even in this respect Chignik Bay examples vary somewhat.

Among the Californian specimens the most important differences are due to age. The small examples have more prominent marginal plates than the medium-sized and large examples, and much fewer pedicellariæ, these being absent from the distal adambulacral plates. The adambulacral pedicellariæ are rare in Californian specimens. Some specimens have mostly four furrow spines to a plate, others three, while still others both numbers; four is the usual number for typical, large examples, though some have three, and less commonly five. There is also variation in the number of granules to the abactinal paxilliform plates, especially of the radial areas. For instance, a specimen with R=42 mm., on the midradial parapaxillæ, at base of ray, has about eighteen to twenty peripheral granules and fifteen to seventeen central. Another specimen with R=59 mm.—consequently larger—has only fourteen or fifteen peripheral and five to ten central granules. The granules vary a little in size, being slenderer and more spiniform in the peripheral series in some examples, crowded and more granuliform in others.

The rays vary in thickness, especially distally, according to whether one, two, or three rows of plates attain the terminal plate. In some examples the actinal intermediate pedicellariæ are higher than the abactinal, and have a shorter base line; in others they are scarcely different from the abactinal.

A remarkable variation is presented by one specimen from the type-locality, Puget Sound. In this example there are numerous small *secondary* abactinal parapaxillæ on the median radial areas (proximally). Practically all the adambulacrals have five furrow spinelets and the first actinal series is set obliquely. There is one six-rayed and one four-rayed specimen in the collection.

Young.—The smallest specimen (station 2934) has R=8 mm.; marginal plates, eight; papulæ restricted to radial areas; tabula low or absent; granules, two or three central and about eight peripheral on proximal radial region; two or three abactinal pedicellariæ; three furrow spinelets; one or two actinal pedicellariæ.

Types.—In Coll. Suckley (Puget Sound), and in U. S. National Museum (California), Cat. No. 1977.

Type-locality.—Puget Sound, Washington, or San Francisco, California.

Distribution.—From the Alaskan Peninsula (Chignik Bay) south to northern Lower California, in shallow water (9 to 160 fathoms).

Specimens examined.—About two hundred and thirty-one specimens from the following stations:

Specimens of Mediaster æqualis examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2873	Off Cape Flattery, Washington	40	rocks	3	U. S. Nat. Mus.
2874	do	27	rocks and shells	8	Do.
2875	do	40	do	14	Do.
2886	Heceta Bank, Oregon	50	rocky	2	Do.
2894	Off San Miguel Island, California	53	broken shells, sand	1	Do.
2906	Santa Barbara Channel, California.	96	sand, mud	4	Do.
2907	do	44	fine gray sand	16	Do.
2908	do	31	gray sand, broken shells	1	Do.
2922	Cortez Bank, off San Diego, California.	47	fine gray sand	1	Do.
2926	Off San Diego, California	69	do	1	Do.
2934	do	36	gray sand	3	Do.
2938	do	47	do	2	Do.
2939	Off Wilmington, California	27	fine gray sand	14	Do.
2942	do	20	gray sand, broken shells	4	Do.
2944	Off Anacapa Island, California	30	rocky	3	Do.
2950	Between Santa Cruz and Santa Rosa Islands, California.	21	gray sand, broken shells	1	Do.

Specimens of Mediaster æqualis examined—Continued.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection
		Fathoms.			
2959	Off San Miguel Island, California	55	green mud, gray sand, broken shells.	8	U. S. Nat. Mus.
2961	Near Santa Barbara, California	21	green mud	4	Do.
2964	do	21	sandstones	1	Do.
2965	do	27	fine gray sand, rocks	4	Do.
2972	do	61	green mud	1	Do.
2974	do	73	do	1	Do.
2975	Off Anacapa Island, California	36	gravel, broken shells	5	Do.
2978	do	46	gray sand	2	Do.
3059	Off Siletz Bay, Oregon	77	mud	2	Do.
3068	Admiralty Inlet, Washington	135	green mud	3	Do.
3080	Off Oregon	93	do	1	Do.
3087	Off Alseya River, Oregon	46	clay and pebbles	2	Do.
3088	do	46	do	3	Do.
3095	Off Heceta Bank, Oregon	42	rocks, stones, broken shells.	1	Do.
3106	Southwest of Half Moon Bay, California.	77	fine gray sand	1	Do.
3108	do	43	rocks, broken shells	1	Do.
3130	Monterey Bay, California	9	sand	2	Do.
3159	Off Point Reyes, California	27	rocky	3	Do.
3160	do	39	do	3	Do.
3184	South of Monterey Bay	77	sand, gravel	2	Do.
3662	Off Avalon, Santa Catalina Island, California.	47	fine gray sand	3	Do.
3663	do	47	do	2	Do.
3664	do	80	do	6	Do.
3665	Off Santa Catalina Island, California.	59	do	3	Do.
	Off Santa Cruz Island, California	30		4	Do.
	Monterey, California			2	No. 8764, D. S. Jordan.
	Puget Sound, Washington			1	Chas. M. Drake.
4228	Near Naha Bay, Behm Canal, southeast Alaska.	41–134	gravel, sponges	1	*Albatross*, 1903.
4281	Chignik Bay, Alaska	42–48	green mud	10	Do.
4311	Near San Diego, California	110–143	green mud, fine sand	1	*Albatross*, 1904.
4343	Near Los Coronados Island, Lower California.	55–155	fine gray sand	2	Do.
4414	Between Santa Catalina and Santa Barbara Islands, California.	160–141	fine gray sand, mud, rocks	2	Do.
4420	Between Santa Barbara and San Nicholas Islands, California.	38–32	fine gray sand	3	Do.
4431	Near Santa Cruz Island, California	30–41	mud, gray sand, rocks	9	Do.
4439	Monterey Bay, California	42	gray sand, broken shells	1	Do.
4460	do	55–167	green mud, gravel	1	Do.
4467	do	54–51	soft dark green mud	1	Do.
4534	do	86–76	hard sand	1	Do.
4551	do	56–46	rocks	1	Do.
4552	do	83–66	green mud, rocks	1	Do.
4553	do	74–65	rocks	4	Do.
4554	do	60–81	green mud, rocks	5	Do.
4555	do	66–69	do	4	Do.
4559	do	22–8	fine gray sand.	2	Do.
	Yes Bay, Alaska			1	*Albatross*, [illegible]
4 stations.	Off San Pedro, California	23–40	green mud and sand	24	University of California.
	San Diego, California			1	Do.
	Puget Sound			7	Stanford collection.

Remarks.—This species is occasionally caught by fishermen in Monterey Bay and Puget Sound. Its life colors are very bright. It seems to inhabit several kinds of bottom ranging from rocks and shells, hard sand, gravel, clay, and pebbles, to green mud, and a mixture of mud and rocks.

MEDIASTER TENELLUS Fisher.

Pl. 36, figs. 1, 2; pl. 57, figs. 3, *3a–d;* pl. 59, fig. 2.

Mediaster tenellus Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 307.

Diagnosis.—Rays five. R = 58 mm.; R = 19 mm.; R = 3r. Breadth of ray between first and second superomarginals, 20 mm; at middle of ray, 7 or 8 mm. General form flattened; disk large; rays fairly long and slender, tapering abruptly at base, then more gradually; interbrachial arcs very wide, and rounded; abactinal surface inflated on radial areas, sunken on interradial areas, the rays especially being convex; actinal surface considerably inflated on disk; marginal plate small, confined nearly to sides of body; abactinal area with tabulate plates or parapaxillæ having an ornate crown of numerous prismatic spinelets, and often a small upright two-jawed pedicellaria; adambulacral plates with five long strongly compressed furrow spinelets, and three actinal spinelets about three-fourths as long; a few adambulacral and actinal intermediate pedicellariæ with high slender jaws. Rudimentary superambulacral plates present; internal ossicles connecting abactinal plates of papular area; papulæ single.

Description.—Abactinal area covered with ornate, regularly spaced parapaxillæ or tabulate plates, largest in a regular median radial series, decreasing thence toward tip of rays and margin of disk; paxillæ of median radial series elongated transversely, the others roundish; the former bearing on the periphery of the tabulum fifteen to seventeen prismatic, blunt spinelets, as long as, or slightly longer than, the lesser dimension of the tabulum and decidedly longer than is usual in this genus; in the center are six or seven irregular, prismatic, pointed granules, much shorter than the peripheral spinelets; ornamentation of the other paxillæ differing only in having fewer spinelets and granules. At the tip of the ray the plates lose their tabulate character. Many of the paxillæ bear on the edge or nearer the center, a small upright pedicellaria, whose two broadly spatulate concave jaws are slightly higher than wide and very much larger than the central granules. They are nearly as long as the marginal spinelets, and curve inward slightly toward each other.

Abactinal plates, viewed from the cœlomic side, are seen to be well spaced, transversely elliptical or roundish with slight indications of lobing. The median radial plates are considerably wider than long. All plates of the papular areas are connected by internal radiating ossicles, but these are less regular than in *æqualis.* Between the radial and either adradial series there are sometimes two or even three shorter ossicles end to end. There is only one conspicuous papula to an area, not two or three as in *æqualis.* They are absent from the tip of rays and a small interradial triangular area adjacent to the marginal plates.

Marginal plates rather smaller than in any other species of the genus, and throughout most of the ray the superomarginals are confined to the side wall; thirty in number from median interradial line to extremity of ray, thin, slightly longer than high throughout most of ray, and forming a slightly arched, steep bevel to side of body; first plate conspicuously higher, or wider, than long, and longer on inner than lower edge. General surface covered with evenly spaced thimble-shaped granules which increase in size toward the center of each plate, the peripheral being rather small and pinched. A few plates bear pedicellariæ similar to those of the paxillæ. Inferomarginals beyond the second plate alternating with superomarginals and wider than high, forming a narrow border to the actinal area. thin, slightly longer than broad, and the upper edge angular, like the lower edge of the superomarginals; granulation rather coarser than that of superomarginals, square or prismatic, and very few pedicellariæ on the series.

Adambulacral plates rather regularly quadrate and remarkable for the long furrow spinelets, of which there are five in each series, strongly compressed, regular, round-tipped, the adoral slightly shorter than the other four, these spinelets reaching nearly across the furrow and tapering slightly as regards their thickness, the tip being often beveled; on the actinal surface a longitudinal series of three spinelets, the central longest and about three-fourths the length of the furrow spinelets, the series standing midway between furrow margin and outer margin, upon which are three or four less regular granules similar to those of the actinal intermediate plates; first plate and a few others with a peculiar foraminate pedicellaria on actinal surface consisting of two or three slender upright spiniform jaws, occasionally faintly spatulate, nearly as high as the inner actinal series. (Pl. 57, fig. 3*b*.) These pedicellariæ do not have a depression into which the jaws fit when opened.

Mouth plates slightly convex actinally and the furrow armature consisting of eight spinelets, similar in character to those of the adambulacral plates; the two inner larger than the others, and those between inner and outer members of the series slightly shorter, or, in other words, graduated in size from the middle toward either end of the series; on actinal surface a number of elongate granules, and one of the peculiar pedicellariæ, the latter situated near the median suture at about middle of plate.

Actinal interradial areas large, the plates extending to ninth inferomarginal or about half the length of ray, arranged quite regularly in series parallel to the furrow, slightly convex and armed with six to eight spaced, elongate, prismatic granules, usually forming an ornate rosette. A few plates have a pedicellaria with slender, high, jaws. (Pl. 57, fig. 3*c*.)

Madreporic body convex, oval, situated nearer than midway to margin; striations coarse, undulating, interrupted, centrifugal.

Anatomical notes.—This species possesses rudimentary superambulacral plates. It is necessary to treat the ambulacral and adjacent plates with caustic potash solution. After this is done the small independent oval ossicles are seen at the lower end of the ambulacral plates. They are very similar to those of *M. æqualis*. They were examined on eleven plates at about the middle of the ray. It was not thought desirable to mutilate the type further to ascertain if the superambulacrals extended to the very base of the series, as this point is not of great importance.

Young.—A young specimen from station 4421 has the following dimensions: R = 13 mm.; r = 6 mm. It has the general facies of the adult, but all the paxillæ are roundish, the median radial with one central and six to nine peripheral terete blunt spinelets. There are four long furrow spinelets and one of the two or three actinal adambulacral spinelets is longer than the rest. The marginal plates are more conspicuous in the adult.

Type.—Cat. No. 22337, U.S.N.M.

Type-locality.—*Albatross* station 4427, off Santa Cruz Island, California, 447 to 510 fathoms, black mud, rocks. A young specimen from station 4421, between Santa Barbara and San Nicholas Islands, 291 to 229 fathoms, gray mud, rocks.

Distribution.—Southern California south probably intergrading with *M. transfuga* Ludwig of the Panama fauna (the two species may be the same). Found in 291 to 510 fathoms.

Remarks.—The species most closely related to the present is *Mediaster transfuga* Ludwig (1905) from the vicinity of Acapulco, 902 meters. It is probable that the two forms are merely extremes of the same species, as the outward habit and most of the structural details are essentially the same. *M. transfuga* has slightly longer rays and longer lobes to the dorsal plates; the area of the internal connecting ossicles is somewhat more restricted (possibly due to younger specimens); there are fewer spinelets to the dorsal paxillæ; adambulacral spinelets are shorter (?), especially on the actinal surface of plate; the actinal pedicellariæ when present are like the dorsal; in *tenellus* they are much higher, almost spiniform. Probably rudimentary superambulacral plates are present in *transfuga* and escaped notice. It is impossible to tell how much the characters of typical *tenellus* vary, as only one adult was taken by the *Albatross*.

The *Mediaster elegans* described by Ludwig in the same paper (1905, p. 125) is not a *Mediaster*, as it lacks the distinctive characters of the genus.

Mediaster tenellus is remarkable for the small marginal plates, the high, slender, pedicellariæ of the actinal surface, and for the unusually long furrow spinelets. The peripheral spinelets of the abactinal paxillæ are also more elongate than is usual in the genus. The species is therefore far removed from *æqualis*, the type of the genus.

Genus CERAMASTER (Verrill).

Ceramaster VERRILL (Sec. C of *Tosia*), Trans. Conn. Acad., vol. 10, 1899, p. 161. Type, *Asterias granularis* Retzius.—FISHER, Bull. U. S. Fish Comm. for 1903, pt. 3, 1906, p. 1054 (subgenus).

Pentagonaster AUTHORS (not Gray) in part.

Tosia VERRILL (not Gray) in part, 1899.—FISHER, 1905.

Mediaster VERRILL in part, 1899.

Philonaster (subgenus) KŒHLER, Deep Sea Asteroidea collected by the Roy. Ind. Mar. Surv. Ship *Investigator*, 1909, p. 74. Type, *Pentagonaster* (*Philonaster*) *mortenseni* Kœhler.

Diagnosis.—Goniasteridæ with a pentagonal, arcuate pentagonal or very short-rayed form; with the abactinal plates entirely covered with granules, those of papular areas with more or less elevated (sometimes almost paxilliform) tabula, the base being slightly to conspicuously lobed; marginal plates granulated, sometimes with a plane or tumid naked area; actinal intermediate plates always granulated; adambulacral plates with two to eight furrow spinelets, their actinal granules frequently in series, graduated in size between furrow spinelets and actinal intermediate granules; the first actinal adambulacral granules or spinelets sometimes slightly spaced from furrow series as in *Mediaster*. Pedicellariæ bivalved or with two or three spatulate jaws; absent in type. No trace of rudimentary superambulacral plates, such as occur in *Mediaster;* no internal abactinal radiating ossicles connecting the plates.

Remarks.—This genus is better characterized than any other nearly related group, and while the species included in it are quite diverse in some particulars, they hang together fairly well in respect to the structure of the abactinal, marginal, and actinal intermediate plates. The genus *Tosia*, as limited by Verrill in 1899 and adopted by me in 1906, is too comprehensive. *Plinthaster*, a section of *Tosia* under Verrill's classification, is very different from *Ceramaster*, as I found after having examined *Plinthaster perrieri*, *P. comptus*, *P. nitidus*, and *P. dentatus*. As explained above (p. 165), *Pyrenaster* does not seem to me to be separable from *Plinthaster*. *Plinthaster* has flat, naked abactinal plates, while in *Ceramaster* the plates are granulated and there is a distinct tabulate structure. The *Tosia* (*Ceramaster*) *micropelta* described by me in 1906 is not a *Ceramaster*, as it has small, round, flat, granulated plates, with intermediate smaller plates on the central part of the disk and proximal radial regions. It belongs to *Peltaster* or a closely related genus.

Of the list of species given by Verrill (1899) as belonging to *Ceramaster* I would not include, without personal examination, *mammillatus*, *hæsitans*, and *pulvinus; placenta* is in many respects an aberrant member of this group, though I have not seen specimens. The tabulate form of the plates of the papular areas seems to be minimized. In formulating our conception of a genus we hark back to the type, in this case *granularis*. Typical species, as *granularis* and *patagonicus*, stand about midway between such extremes as *japonicus* and *placenta*. *C. leptoceramus* with its secondary abactinal plates in adults is decidedly aberrant, though apparently near to *japonicus*. It might be made the type of a new subgenus. *C. arcticus*, with the exceptionally extensive papular areas, short adambulacral plates, and few furrow spinelets, is still another variant from the typical form of structure.

Perhaps the nearly related genera which can be grouped about *Ceramaster* are *Nereidaster*, *Mediaster*, *Tosia* (as here used, a very restricted austral genus), and *Peltaster*, with *Plinthaster*, *Eugoniaster*, and *Pentagonaster* in an outer circle. *Mediaster arcuatus* (Sladen), which has usually been classed as *Pentagonaster*, but which possesses the internal independent radiating ossicles of *Mediaster æqualis* shows how near the two groups approach in external appearance. From the original figures and description Professor Verrill was led to place *C. japonicus* and *patagonicus* in *Mediaster*, but they are more nearly allied to *C. granularis* and must therefore be classified in *Ceramaster*. *C. placenta* seems to tend toward *Tosia*. This small group, as already explained, is homogeneous enough to form an independent genus. *Plinthaster* and *Eugoniaster* are its nearest relatives, next to *Pentagonaster* (restricted). *Peltaster* has small flat (not tabulate) granular abactinal plates, with few to many secondary ones among them. If the aberrant *P. micropelta* (Fisher) is admitted to the genus the form of the pedicellariæ and the adambulacral armature will have as great a range as in the most diverse species here classified under *Ceramaster*.

KEY TO THE SPECIES OF CERAMASTER HEREIN DESCRIBED.

a^1. A well-defined more or less triangular interradial area free from papulæ; papulæ single; interradial abactinal plates never lobed; furrow spinelets four or more.
  b^1. Furrow spinelets numerous, six or more proximally; abactinal tabula well spaced, rather convex, with many small crowded granules, of which the marginal series is sensibly smaller.
    c^1. No abactinal secondary plates; actinal intermediate granules flat and closely crowded; furrow spinelets about six proximally; margin of disk typically thicker; pedicellariæ low, bivalved. *japonicus*, p. 206.
    c^2. Secondary abactinal plates on radial areas; actinal intermediate granules well spaced, beadlike; furrow spinelets seven or eight proximally, slender; disk very thin and margin thin; pedicellariæ with short spatulate jaws.................................*leptoceramus*, p. 210.
  b^2. Furrow spinelets usually not more than five; proximally abactinal tabula closer, with larger, fewer granules, the marginal granules being equal to or larger than the central ones.
    c^1. Superomarginal plates usually with a tumid bare spot; the granules small and crowded, forming a smooth pavement; abactinal tabula with numerous central granules; adambulacral plates proximally as wide as long and first actinal series not enlarged into conspicuous stubby tubercular spinelets...*patagonicus*, p. 214.
    c^2. Superomarginal plates small, only a few distals with a tumid bare spot, their granules coarse and hemispherical; abactinal tabula with few granules; adambulacral plates proximally narrower than long, with four long furrow spinelets and a series of actinal spinelets. *clarki*, p. 217.
a^2. Papulæ distributed all over abactinal surface, usually two to four in a group; all abactinal plates lobed; furrow spinelets two or three; adambulacral plates very short, more than twice as wide as long..*arcticus*, p. 219.

CERAMASTER JAPONICUS (Sladen).

Pl. 37, figs. 1–3; pl. 59, fig. 3.

Pentagomaster japonicus Sladen, *Challenger* Asteroidea, 1889, p. 272, pl. 46, figs. 1 and 2; pl. 49, figs. 1 and 2.
Mediaster japonicus Verrill, Trans. Conn. Acad., vol. 10, 1899, p. 179.

Diagnosis.—One of the largest if not the largest species in this or any closely allied genus. R=102 mm.; r=65 mm.; R=1.56 r (varying to R=1.36 r). General shape pentagonal or arcuate pentagonal, depressed, the edges of body more or less thickened; abactinal surface usually swollen on the radial areas; actinal surface nearly plane. Abactinal surface covered with fairly regular, spaced, hexagonal to quadrate tabula crowned with a convex group of numerous polygonal granules, the marginal series regular, sometimes compressed, and when dried showing a pit in the top. On the interradial areas tabula are quadrate and smaller. Many of the tabula with a bivalved pedicellaria, having thin, lamelliform jaws which are wider than high. These vary in size, equaling one-third or one-fourth the width of the tabulum. Marginal plates variable, covered with small flat crowded granules, forming an evenly rounded, or a decidedly tumid margin to ray; a bare space sometimes present on plates of both series, each superomarginal, with one to four small bivalved pedicellariæ, whose thin jaws equal two to four granules in width. These are situated usually on the abactinal surface of the superomarginals near the margins; inferomarginals with usually only one pedicellaria or none. Actinal intermediate areas very extensive, the plates decreasing in size toward margin, and covered with crowded low flat polygonal granules, of which the marginal are slightly the largest; individual plates perfectly flat and variously four-sided; actinal intermediate pedicellariæ in variable numbers. Adambulacral plates usually slightly wider than long, with a slightly oblique furrow series of five or six (four to seven) round-tipped, four-sided, often somewhat flattened, stout spinelets, frequently graduated in length toward the adoral edge of plate, or all but the shorter adoral number subequal. Actinal surface with three to five irregular longitudinal series of low granules, those nearest the furrow spinelets being largest. A bivalved pedicellaria is normally present on most of the plates, the jaws being usually wider than high, but exceptionally higher than wide. The granules of actinal surface of adambulacrals vary greatly in number and those on the outer half are not in very definite series.

Madreporic body pentagonal situated one-third distance from center to inner edge of marginal plates.

Anatomical notes.—Anal opening present, subcentral surrounded by three to six plates larger than those adjacent. Intestinal cœcum large, with eight long, unequal glove-finger-like radiating divisions. Intestine spacious, stomach small; hepatic cœca long, extending two-thirds to three-fourths length of R; quite a sharp distinction between dorsal and ventral divisions of stomach. Gonads very large, bushy, each with four short ducts and four apertures in a line parallel to and a short distance from the tough, uncalcified interradial septum. Dorsal muscle bands stout, joining at center of disk. Each band gives off numerous lateral smaller branches, obliquely like the barbs of a feather, on the side toward margin. Polian vesicles large, one in each interradius except that of the madreporic canal; ampullæ double; tube feet with large sucking disks. No superambulacral ossicles.

When the plates which bear the tabula are examined from the inner surface of the stout dorsal integument they are seen to be arranged in very regular rows parallel with the median radial. The radial row and the two on either side have plates with six short, broad, rounded, or truncate lobes. On either side of these the lobes are very soon lost and the plates become circular. All plates are slightly spaced and there are no internal connecting ossicles as in *Mediaster*. Papulæ are single and distributed all over the abactinal surface, except in a narrow interradial band reaching toward center of disk as far as the madreporic body; they are absent also at the tip of ray; four to six, or even more, occur around each plate, according to its size and shape.

Variations.—The examination of seventy specimens of this species, including one from off Misaki, Japan, 640 meters, kindly sent by Dr. Seitaro Goto, of Tokio, reveals a considerable range of individual variation. The differences which the American specimens seem to present are greatly overshadowed by individual differences occurring in examples from the same station. Sladen apparently had only one specimen, and of course could give no hint of this variation in his excellent description.

General form, etc.—Some specimens are more arcuately pentagonal than Sladen's figure and of the same form as his figure of *patagonicus*. The Misaki specimen is about intermediate in form. The Washington specimens are less arcuate than many of those from Bering Sea. The abactinal area varies in the amount of inflation, and corresponding to this the interradial sulcus is more or less evident. There is one four-rayed example.

Abactinal plates.—Two large specimens from stations 3330 and 3331, Bering Sea, in practically the same locality exhibit very nearly the extremes of variation in the size of plates (Pl. 37, figs. 1 and 2). That from station 3330, specimen A (fig. 2) has R=92 mm., while B has R=91 mm. In A the largest tabula of the median radial region are 3 mm. in diameter, in B 3.5 mm., but in A there are relatively much fewer large tabula and the spaces between them are much wider than in B, as will be seen from the photographs. This difference in the size of the tabula and in the extent of space between is duplicated in other localities. The larger tabula have larger granules, not a correspondingly greater number; eighteen to twenty-four marginal granules and eighteen to thirty in the central group is the range in large specimens. In dried specimens the marginal granules are concave on the top, the others are flat. Pedicellariæ are usually very numerous, occurring on a majority of plates of the papular areas.

Marginal plates.—The greatest variation of all is in respect to the marginal plates. Typically these form a tumid rounded border, but exceptionally are nearly as thin as in *leptoceramus.* Again, the two specimens mentioned above will serve to illustrate the extremes of size. In A, which is less typical, the plates are entirely covered with close, flat granules and measure in the interradius 4 mm. by 4 mm., being less regular in size and not at all tumid. The thickness of the edge of the disk is 5 mm., which includes the height of the combined plates. In B the plates are very regular, 5 mm. long by 6 wide, and the edge of the disk is 8 mm. thick. The superomarginals are strongly tumid, but entirely covered with granules except for a few distal plates. In A there are forty-two to forty-four superomarginals and about fifty inferomarginals to a side of the pentagon; in B thirty-six superomarginals and forty-two inferomarginals. In typical *japonicus* as described by Sladen the superomarginals all had an extensive tumid bare space on the abactinal surface, and the inferomarginals a smaller one on the actinal surface. The size of this spot is variable even when it is present. In my Misaki specimen the spots are smaller than those described by Sladen. One of the Washington examples has the bare spaces (on superomarginals only) about as in the Misaki specimen; three others lack them. Out of twenty-four specimens from station 3608 only three have a bare spot on the superomarginals and inferomarginals. A small specimen from 3331 has fairly large tumid bare spots, while a large example ("B") lacks them. The shape of the plates is variable. In specimens with large marginals the width is greater than length, but when the plates are small and not tumid the proximal plates may be square or even longer than wide. The extreme in this respect is a specimen from station 4775 which has proximal plates 4 mm. long by 3.25 wide. Japanese specimens vary in this respect, as the type had longer proximal superomarginals than the Misaki example, which has the plates decidedly wider than long throughout. A remarkable variation is exhibited by a specimen from 4774, which has the marginal plates slightly concave, the transverse sutures being on the summit of a tumidity. The number of pedicellariæ on the superomarginals varies greatly, two or three are commonly present, sometimes three or four on all except the most distally situated. The inferomarginals sometimes lack pedicellariæ, but usually most of the plates have one or even two which are slightly larger than the superomarginal ones.

Actinal intermediate plates.—A characteristic of this species is the very crowded polygonal, flat-topped, smooth actinal intermediate granules. They are not at all globular, and this character seems fairly constant. It is well marked in the Washington specimens and serves admirably in connection with other features to separate *japonicus* from *leptoceramus.* The latter species has spaced hemispherical granules.

The small bivalved pedicellariæ vary considerably in numbers. They may be restricted to the angle adjacent to mouth plates, or scattered part way or all along the row of plates adjacent to adambulacrals. Many specimens, but not a majority, have them also sparingly elsewhere on the intermediate areas (Misaki, Washington, Bering Sea.)

Adambulacral plates.—In proportions the plates vary from being as wide as long to wider than long. The outer edge is frequently oblique or obtusely angular. The furrow spinelets are prismatic or subquadrate in section, blunt, usually but not always with a slightly curved, oblique, base-line. The Washington examples have proximally four or five, rarely six, furrow spinelets, distally three to five; the Misaki specimen proximally six or seven, distally six spinelets, and the base line is more evidently oblique. Large Alaskan examples have proximally five or six spinelets, distally four or five. Young Alaskan specimens (R=30 mm.) have four or five furrow spinelets throughout. The Misaki specimen has rather shorter spinelets than the Alaskan and Washington examples. The first series of actinal granules varies from three to five. Far along the furrow one of these granules is enlarged into a blunt tubercle. The bare space between the furrow spinelets and first series of granules is variable in width, wider in the Japanese specimen than in the Alaskan or Washington examples. The number of granules exclusive of the first series varies from about twelve to twenty-two. The small number occurs when there is a pedicellaria on the plate. In specimen A, before cited, very few of the adambulacrals have pedicellariæ. In the Misaki example nearly all have one. Nearly as great a range of difference is present in the Washington examples, and in Bering Sea specimens, as, for example, station 3608.

Young.—The young bear a great resemblance to *C. granularis* (Retz.). In this species, however, the superomarginals are longer than wide, whereas all the young *japonicus* have them wider than long. *Granularis* lacks pedicellariæ altogether, the abactinal tabulæ are flat-topped with large marginal granules, and the actinal intermediate granules are roundish and not crowded. The adambulacral armature is coarser and the spinelets and granules fewer. In young *japonicus* the papulæ are restricted to broadly ovate areas on the radii, the tabula are lower with fewer granules, and no abactinal pedicellariæ or only few. The marginal plates are sometimes relatively thicker than in the adult.

Type.—In the British Museum.

Type-locality.—*Challenger* station 232, south of Yokohama, Japan, 345 fathoms, green mud.

Distribution.—Japan (Misaki, and south of Yokohama) to southern Bering Sea, thence south along the American coast to Oregon.

Specimens examined.—Seventy-three, from the following localities:

Specimens of Ceramaster japonicus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
3227	Bering Sea, north of Unalaska	225	green mud	4	U. S. Nat. Mus.
3330	do	351	black sand, mud	1	Do.
3331	do	350	mud	5	Do.
3346	Off Tillamook Bay, Oregon	786	green mud	4	Do.
3488	West of Pribilof Islands, Bering Sea	106	green mud, gray sand	1	Do.
3489	do	184	do	2	Do.
3502	Bering Sea, south of St. George Island	368	green mud, dark sand	26	Do.
3608	Bering Sea between St. George and Unalaska	276	gray sand	24	Do.
4768	Bowers Bank, Bering Sea, 54° 12′ N.; 179° 07′ E.	771	green mud	1	*Albatross*, 1906.
4774	Bowers Bank, Bering Sea, 54° 33′ N.; 178° 45′ E.	557	green mud, black speck, foraminifera.	1	Do.
4775	do	584	do	3	Do.
	Misaki, Japan	320		1	Stanford.

Remarks.—In lieu of giving a detailed description of this species, I have listed the chief variations presented by a large series of specimens. The various figures will serve sufficiently, in connection with Sladen's excellent description of the type-specimen, for purposes of identification. Except in the case of young specimens there is no danger of confusing this species with *C. granularis,* to which it seems to be rather closely related. The salient differences have been already pointed out. The differences between *japonicus* and *leptoceramus* are mentioned below under the latter species.

CERAMASTER LEPTOCERAMUS (Fisher).

Pl. 39, figs. 1–3; pl. 58, figs. 3, *3a;* pl. 60, fig. 2.

Tosia leptocerama FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 306.

Diagnosis.—Related to *C. japonicus* Sladen, but with secondary abactinal plates, thinner disk and margin, spaced bead-like actinal granules, and shorter and more numerous furrow spinelets. Type, $R=63$ mm.; $r=44$ mm.; $R=1.43$ r. Disk thin, general form pentagonal, marginal plates small, closely granular, sometimes with a bare spot; superomarginals not in contact distally; radial areas inflated; body very thin interradially (about 1.5 mm.). Abactinal plates stellate on papular areas, raised into spaced tabula bearing numerous granules and usually also a small two-jawed pedicellaria; numerous smaller secondary plates intercalated between the larger ones on proximal part of papular areas. Actinal intermediate plates with spaced bead-like granules and two-jawed pedicellariæ. Adambulacral plates with a regular furrow comb of seven or eight short compressed quadrate slender spinelets, and two rows of actinal granules.

Description.—Abactinal surface covered with spaced, low, tabulate plates, arranged with great regularity in a radial series, which is largest, and numerous other parallel series, decreasing rapidly in size toward the margin, where the plates are small and more crowded. In center of disk the plates are arranged without order, and are more or less irregular in a narrow interradial area, which is free from papulæ. Bases of plates of radial areas, when viewed from the inner side, in a prepared specimen are substellate, regularly with six truncate or blunt processes, a shallow sulcus running from the center of the plate to each interradial angle. The plates are entirely free from one another, those of the radial and either adradial series being lengthened transversely, the others rounder. In the vicinity of the marginal plates they become more crowded and lengthened longitudinally. In the center of disk the plates are roundish, and in the narrow interradial area quadrate, hexagonal roundish, lozenge-shaped, or, near margin, oblong. In the proximal portion of the radial areas, small secondary plates or paxillæ, with narrow ossicle-like bases, are interspersed rather irregularly, but form a fairly regular series between the radial and either adradial row of plates. The low tabulum surmounting each plate is slightly convex, hexagonal to elliptical on radial areas, roundish to irregularly quadrate interradially, elliptical and compressed near border, and bears a central group of robust, flat-topped, quadrate or polygonal granules (about ten to fifteen on radial plates) surrounded by a peripheral series of smaller, square-tipped, flattened regular granules. The granulation does not appear crowded. Nearly all the plates bear one or two delicate pedicellariæ with thin wide-spatulate jaws, higher than the granules. At the edge of the disk where the plates are very irregular, only the marginal series of granules may be present on account of the compression of the plate. The papulæ are conspicuous on account of the open character of the tabulate armature, and are distributed as in *C. japonicus*. The abactinal membrane is rather flexible, the plates not being in contact.

Marginal plates more or less elongate and, owing to the thinness of the disk, rather small; except for the first two or three plates, the members of the two series alternate. Superomarginals, fourteen in number from each interradial line to extremity of series, or twenty-eight to each side of disk, about as high as broad, and much longer than high, except at the end of the series, where they are shorter. These plates form a narrow border to the abactinal area and are covered with a rather uniform, dense, polygonal granulation, a peripheral series being readily distinguishable. The outer plates, or sometimes all, have a small naked area on abactinal face, bearing one to three small, two-jawed pedicellariæ, larger than the granules. Sometimes on the proximal plates only a narrow area about each is left free by the granules; lower margin of each superomarginal angular, forming two facets for articulation with two inferomarginals.

The inferomarginals, sixteen to a ray or thirty-two to a side, are much wider than high, and encroach farther upon the actinal area than do the dorsal series upon the abactinal. The total width of the plate in large specimens is often less than the length, but in smaller specimens the width equals, or exceeds the length. This is true of some large examples. In the middle of the actinal surface is a small naked area, increasing in size toward outer end of series, which bears one to three small, two-jawed pedicellariæ, but slightly larger than the granules. There is considerable variation as to the extent of the naked areas, which are much reduced on some specimens. Granulation of inferomarginals similar to that of superomarginals.

Adambulacral plates nearly square with a straight or slightly curved furrow margin. Armature consists typically of a furrow series of eight or seven untapered, compressed, square-tipped spinelets about half as long as the length of the plate, subequal or slightly shorter at either end, very regular and standing parallel. These spinelets are four-edged, or quadrate in section. On the actinal surface are two irregular longitudinal series of smaller granules, the inner well spaced from the furrow spinelets as in *Mediaster*, and consisting of three or four compressed, square-tipped, sharp-edged granules, larger than those of the outer series. These are very irregular in distribution, eight or nine in number, and similar to, but a trifle larger than the actinal intermediate granules, which they resemble but are usually less regular in form. There are sometimes two irregular rows of these smaller outer granules. At adoral end of inner actinal series is a pedicellaria with two broadly spatulate jaws, slightly larger than the granules of the series, which the pedicellaria greatly resembles when the jaws are closed; at tip of "ray" there are four to seven spinelets in the furrow series, and on the actinal surface a blunt, prominent tubercle, surrounded by several granules, this tubercle grading into the granules of the inner actinal series. The pedicellaria persists to within two or three plates of the tip.

Mouth plates triangular, with a longer furrow margin than the edge adjacent to first adambulacral; furrow series consisting of ten to thirteen spinelets similar in character to those of adambulacrals, but increasing in size toward inner angle, where there is an oblanceolate, blunt, flattened, or compressed tooth, the other spinelets square in section or slightly compressed. On actinal surface is a linear series of low, squarish granules adjacent to the median suture, several others along the aboral edge, and two or three intermediate between the superficial and marginal series.

Actinal interradial areas very extensive; intermediate plates quadrate, roundish, or irregular, those adjacent to the adambulacrals much larger than any of the others, and usually oblong in shape, the short end toward furrow. The plates are arranged in rows parallel to furrow, considerable irregularity existing. Plates are covered with numerous uniform, hemispherical, bead-like granules distinctly spaced. Pedicellariæ similar to those of adambulacral plates scattered here and there, especially near the furrow, but their numbers subject to great variation. They are not so numerous as in *C. japonicus*. The appearance of the spaced, round, bead-like granules is strikingly different from the crowded, flat, polygonal granulation of these areas in *C. japonicus*.

Madreporic body unsymmetrically pentagonal, larger than any of the plates, situated one-third distance from center to margin. It is slightly convex and has branching ridges radiating from an eccentric point.

Color in life, vermilion, yellowish on actinal surface.

Anatomical notes.—The internal anatomy is very similar to that of *C. japonicus*. The intestinal cœcum, in the specimen examined, is large with four principal divisions, two of which are divided at the end. The gonads form a series, on either side of, and parallel to the interradial septum. There are five to eight tufts in each series. The dorsal muscles are arranged as in *C. japonicus* but are much weaker.

Variations.—The variations in this species parallel to a considerable degree, those of *C. japonicus*. The general shape ranges from a nearly straight-sided pentagon (R = 1.31 r) to very broadly stellate (R = 1.5 to 1.73 r) the latter being young specimens; there are also pentagonal examples among the young. The tabula of the abactinal plates are broader on the radial areas of some examples; corresponding to this, the typically wide spaces between the tabula are narrower. The tabula of the radial area are sometimes less regular in form, being nearly elliptical. In young specimens the secondary intermediate plates of the abactinal radial areas (with their small tabula and few granules) are confined to the vicinity of the proximal radial plates. As the size increases the secondary plates extend farther toward tip, and spread out laterally till they are scattered over nearly all the proximal half of the papular areas. These intermediate plates have roundish to triangular groups of granules, frequently bear a pedicellaria, and are never half as large as the adjacent plates. When a large primary tabulum bears fourteen central and about twenty-four smaller peripheral granules, a secondary tabulum has one to eight central and seven to twelve peripheral granules; the smallest have as few as four or five peripheral granules only.

While abactinal pedicellariæ are variable in numbers they are always numerous.

Young specimens usually have a thicker margin in proportion to size than the large ones. The proportions of the plates vary from wider than long to longer than wide in the interradial region; distally they are always wider than long. Near the inner edge of the plates more or less of a bare space is generally present which increases in size toward the end of the "ray." Sometimes only the distal plates of the series have it.

The range of variation in the thickness of margin is not so great as in *C. japonicus;* the margin is normally thin and the plates are not tumid.

The granules of the actinal intermediate plates are low hemispherical, bead-like, and always spaced. The pedicellariæ may be confined to the angle adjacent to mouth plates, and hence few, or else scattered all along the first row of intermediate plates, and sometimes a few occur here and there elsewhere on the interradial regions.

Normally the furrow spinelets form regular combs which have a gently convex distal contour, there being a well marked bare space between them and the first actinal series of granules, which are low, compressed, and elongated longitudinally, three to five in each series.

Type.—Cat. No. 22336, U.S.N.M.

Type-locality.—*Albatross* station 4378, off Point Loma, near San Diego, California, 376 to 594 fathoms, green mud and sand.

Distribution.—Off southern California, between San Diego and Point Conception, 216 to 638 fathoms.

Specimens examined.—Sixty-two from the following localities:

Specimens of Ceramaster leptoceramus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms.			
2937	Off Southern California, east of San Clemente Island.	464	green mud	10	U. S. Nat. Mus.
	Locality not known			8	Do.
4378	Off Point Loma, near San Diego, California	376-594	green mud and sand	1	*Albatross* 1904.
4407	Between San Clemente and Santa Catalina Islands, California.	334-600	rocks, shells, fine gray sand.	2	Do.
4415	Between Santa Catalina and Santa Barbara Islands, California.	638-302	green mud	1	Do.
4416	Between Santa Barbara and San Nicholas Islands, California.	448-323	dark green mud	4	Do.
4423	do	339-216	shells, black pebbles, green sand.	1	Do.
4427	Off Santa Cruz Island, California	475-510	black mud, broken stones.	35	Do.

Remarks.—This species probably ranges considerably north and south of its present known distribution. It shows no signs of intergradation with *C. japonicus* to which it is more nearly related than to any other known species. From *japonicus* it differs in having secondary intermediate abactinal plates on the radial areas, higher tabula, typically thinner margin, spaced bead-like actinal intermediate granules, shorter and more numerous furrow spinelets, much more numerous actinal adambulacral granules. The same characters will serve to distinguish the young also. Small *leptoceramus* have much thinner margins, more numerous abactinal pedicellariæ, more distinctly spaced tabula, and more numerous furrow spinelets than young *japonicus*.

The pedicellariæ, especially the actinal, of *leptoceramus* are higher and have more delicate jaws than those of *japonicus*.

CERAMASTER PATAGONICUS (Sladen).

Pl. 37, fig. 4; pl. 38, figs. 1, 2; pl. 60, fig. 3.

Pentagonaster patagonicus Sladen, *Challenger* Asteroidea, 1889, p. 269, pl. 46, figs. 3, 4: pl. 49, 3 and 4.

Astrogonium granulare? Whiteaves, Trans. Royal Soc. Can., vol. 4, 1886 (1887), p. 117 (40 fathoms, Strait of Georgia, off mouth of Qualicum River).

Mediaster patagonicus Verrill, Trans. Conn. Acad., vol. 10, 1899, p. 145.

Diagnosis.—Pentagonal, with straight sides and short rays, or arcuate pentagonal. R=76 mm.; r=52 mm.; R=1.46 r. Abactinal area flat or slightly inflated; body fairly thick; marginal plates massive, the superomarginals more or less tumid, covered with small polygonal crowded granules, except for a bare spot sometimes occupying the whole abactinal face of plate. This bare space may be quite tumid. Inferomarginals with a bare space on actinal surface. Abactinal surface with regular hexagonal tabula radially, square or rhomboid interradially, these crowned by a very slightly convex group of convex (truncate off South America) polygonal granules, the marginal series being slightly larger; edge of tabula sharply cut (South America) or slightly scalloped (Alaska). A pedicellaria with two narrow to broadly spatulate jaws stands on a few of the tabula. The jaws fit into special depressions. Actinal intermediate plates rhombic, squarish, or oblong, covered with coarse slightly to distinctly spaced, quadrate, polygonal, or roundish convex (flat-topped, South America) granules. Broadly spatulate two- or three-jawed pedicellariæ in variable numbers on actinal surface. Adambulacral plates wider than long. Furrow spinelets four or five, robust, more or less compressed, untapered, sometimes subquadrate in section, or with broadened tips, subequal, or graduated toward a shorter adoral member. Back of these on actinal surface is a longitudinal row of two or three heavy granules or short stubby spinelets, sometimes compressed in a longitudinal plane, sometimes subquadrate, with rounded tips. Outside of these is a variable number of granules (about five to eight) similar to but more irregular than those of neighboring actinal intermediate plates. A two-jawed spatulate pedicellaria stands on some of the plates. Mouth plates elongate, plane, with a long furrow margin bearing eight or nine quadrate or prismatic blunt spines (the inner two quite heavy) similar in character to those of adambulacral. Armature of actinal surface variable.

Variations.—The specimens here considered differ in a few minor details from the typical examples dredged by the *Challenger* from near the Atlantic entrance to the Straits of Magellan. It is possible that these represent a new and very closely allied species, but in view of the individual variations exhibited, and the absence of typical examples for comparison, I would feel considerable hesitation in instituting a new species. The specimen from the Gulf of California points to a continuous distribution along the west coast of the Americas, but there is too little data for any generalization.

The Alaskan examples have fewer and convex granules on the abactinal tabula (not truncate and crowded) and the edges of the tabula are not so straight cut but are a trifle scalloped owing to the slightly convex outer edges of the peripheral granules. The actinal intermediate plates have more distinctly spaced and round-topped granules, appearing hemispherical in some cases. In Sladen's figure the granules appear to be fairly close together and truncate. In the Alaskan specimens the first series of actinal adambulacral granules are slightly longer and more spiniform, but as there is some variation even among the few specimens available it is probable that South American specimens are also variable. The Alaskan examples have with one exception more tumid marginal plates; but the size and tumidity of the bare area is quite variable.

Taking into consideration the eight specimens, the contour varies as Sladen's figures of *C. patagonicus* and *C. japonicus* (Pl. 46), all the Alaskan specimens being like *C. japonicus* with the exception of two young, which are more arcuate. The Gulf of California specimen is also arcuate but not quite so much so as Sladen's figure of *patagonicus*. The superomarginals are wider than long, that is, are transversely oblong, but two specimens have the plates narrower than usual. The size of the bare space varies from a third to over a half of the exposed surface of the plate. Usually but a single row of regular granules borders this space on the inner and one-half the lateral margins. One large specimen, however, has the areas nearly as small as figured by Sladen. A small pedicellaria with two tapering or spatulate jaws stands on the edge of the bare space of a few plates. The bare space is smaller on the inferomarginals and the pedicellariæ when present have shorter jaws and are sunken in shallow pits.

The abactinal surface has very regular low tabula, slightly spaced and hexagonal on the radial papular areas, less regular and tending to roundish on center of disk, square, rhomboid, or even elongate interradially. The primary basal plates are clearly discernible and are larger than any of the others except the central plate, which with three or four slightly smaller companions surrounds the anus. The radial tabula bear a peripheral series of twelve to fifteen and about four to twelve central round-topped low granules, the former slightly the largest. The central granules are polygonal or roundish and do not touch each other. The peripheral have the outer margin longest. In typical *patagonicus* as figured by Sladen the central granules are more numerous, crowded and flat-topped, and the edges of the peripheral are more squarely cut, as if "dressed" with a knife. In Alaskan examples the outer edges of the granules are usually fairly straight, but the granules are not crowded, so that the edge of the tabulum is not such a straight line. In one specimen (station 3257) there is a row of scattered pedicellariæ parallel to and about

5 mm. from the marginal plates. The tabula which bear these are nearly bare, except for the peripheral and a few additional granules. Usually the pedicellariæ have special depressions into which the jaws fit when open.

A specimen from station 4228 has furrow spinelets with thick spatulate tips so that the spinelets taper toward the base. Two very thick, short, stubby spinelets stand in the first actinal row. A comparison of Sladen's figure (pl. 49, fig. 4) with those here published will demonstrate better than a description the range of variation of the adambulacral armature.

Young.—Two small specimens from station 3223. The smaller has R = 15 mm.; r = 10 mm. Form arcuate pentagonal; marginals with conspicuous bare spot; tabula of midradial series with two to six central and nine to eleven peripheral granules which are more flat-topped than in adults. Primary basal plates large conspicuous with a central bare spot. Furrow spinelets three or four, truncate or round-tipped, prismatic or four-sided; two or three compressed spinelets or granules in first actinal series, three to five granules in outer part of plate. Mouth plates with nine or ten marginal spinelets.

Anatomical notes.—Intestinal cœca very large. There is a small central portion, from which radiate four narrow thin-walled tubes. These each divide into two distal thin-walled pear-shaped sacs, which resemble Polian vesicles. In two interradii, these sacs reach as far as the marginal plates, or as far along each radius as the hepatic cœca. Gonads very small, in two tufts on either side of interradial septum and about one-third distance from margin to center. Polian vesicle in four interradii; lacking in that of the madreporic canal. Dorsal muscles weak; arranged as in *japonicus*, but much less conspicuous. Stomach with strong retractors. Ampullæ double, tube feet with sucking disks.

The papular areas are not so extended in large specimens as in *C. japonicus*. They are found in center of disk, inside a circle bounded by the primary basal plates, and on a fairly broad petaloid radial area. They are absent on an extensive triangular interradial area. The abactinal plates of the radial areas show faint lobes and are closely juxtaposed, allowing only a small space for the papulæ to pass between. Interradially the plates are regular, closely joined, and in form, square near center, then hexagonal or pentagonal, and finally rhomboid near margin.

Type.—In British Museum.

Type-locality.—*Challenger* station 313, near the Atlantic entrance to the Straits of Magellan, 55 fathoms, sand.

Distribution.—Vicinity of Cape Horn, Gulf of California, southern Alaska to the southern part of Bering Sea (east to Commander Islands).

Specimens examined.—Nine from the following localities: *Albatross* station 3223, Bering Sea, near Unalaska Island, 56 fathoms, black pebbles, two; 2856, near Kadiak Island, 68 fathoms, gray shells, one; 3257, Bering Sea, near Unalaska Island, 81 fathoms, gray sand, gravel, two; 3548, north of Unimak Island, Aleutians, 91 fathoms, black sand, one; 4228, vicinity of Naha Bay, Behm Canal, southeast Alaska, 41 to 134 fathoms, gravel, sponges, one; 4791 near Bering Island, 76 fathoms, rocky, one; small bay north of Carmen Island, Gulf of California, one (Stanford collection).

CERAMASTER CLARKI Fisher.

Pl. 38, figs. 3, 4; pl. 58, figs. 2, 2*a–b;* pl. 59, figs. 6, 6*a.*

Ceramaster clarki Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 552.

Diagnosis.—R = 53 mm.; r = 33 mm.; R = 1.6 r. General form stellato-pentagonal, but last two or three superomarginals in contact medially. General aspect somewhat resembling *C. patagonicus,* but margins much thinner, marginal plates smaller, their granules coarser, hemispherical, and slightly spaced; the abactinal plates with fewer and larger granules, more numerous and slightly larger pedicellariæ; the actinal intermediate areas with smaller and less regular plates (especially in the series adjacent to adambulacrals), and larger, less regular, thimble-shaped granules; adambulacral plates with subequal, robust, truncate, tubercular spinelets in the first actinal series instead of granules, and the plates narrower than long instead of wider than long.

Description.—The tabula of the abactinal plates are slenderer than in either *patagonicus* or *japonicus* and the marginal granules overhang. One to six convex, roundish or faintly polygonal, unequal, spaced granules occupy the center of tabulum, while seven to fifteen more flattened ones occupy the periphery. The latter have a faintly curved or straight beveled outer margin. The edge of the tabulum is not so square cut as in *patagonicus,* and all the granules are larger and more distinctly spaced. Nearly all the tabula have a pincer-shaped pedicellaria with two or three spatulate or truncate-oblong or even slightly tapering jaws. The figure of the paxillar tabula will give a better idea of their structure and appearance than will a description. Papulæ are absent from near tip of ray and from a small triangular interradial area. On this area the plates are abruptly smaller, with very low circular groups of six peripheral and one or no central granules. This difference in the size and spacing of the plates (these being farther apart on the papular areas) is more conspicuous in *clarki* than in either *patagonicus* or *japonicus.*

The abactinal plates when viewed from the inner or cœlomic side are seen to have a very concave under surface. The plates are strongly lobed and the lobes are turned downward, forming the concavity mentioned. The median radial plates have shorter, broader lobes than either adradial series (where the lobes are spatulate and of unequal length). These lobes appear in many cases to have a suture at the base as if to form incipient independent ossicles. The figure will give a better idea of the form. The high tabula give to the plates of radial areas a decided paxilliform appearance.

Margin of disk evenly rounded, the plates being small and low, the superomarginals forming a roundish bevel. In both series the proximal plates are slightly longer than wide, but about the last five or six are wider than long; and the last two or three superomarginals are conspicuously swollen, with most of the surface bare. In one case the last plate is the largest, but usually it is the penultimate plate. The distal one to three superomarginals are in contact with their fellows of the opposite side of the ray. These distal five or six plates are larger (with the exception usually of the last plate) than the other plates of the series, which are covered with spaced hemispherical granules. Sometimes one or two pedicellariæ similar to those of abactinal surface stand on the superomarginals. The plates of the two series do not exactly correspond, the lower edge of the superomarginals being, in consequence, frequently angular. Superomarginals fourteen, inferomarginals sixteen to the ray.

Inferomarginals are about the same size as the superomarginals, but the distal ones decrease regularly in size, and the last four or five have a tumid bare spot. The granulation is the same as on the upper series, and a pedicellaria is sometimes present. The marginal plates are about as small as in *leptoceramus*. In a small specimen from southern California, very doubtfully referred to this species, the marginals are slightly larger, are all wider than long, and the distal superomarginals are not enlarged.

Adambulacral plates narrow, slightly longer than wide, with a furrow series of four or five (sometimes six), distally three, equal, rather long, compressed, blunt spinelets. These are considerably longer than width of plate and longer even than the length of plate. The two median spinelets are frequently more compressed than the laterals. Immediately behind the furrow spinelets is a longitudinal parallel series of two or three much stouter, cylindrical, blunt, tubercular spinelets about two-thirds the length of the furrow spinelets. Proximally these spinelets are often compressed and quadrate in section. Far along the furrow there are two in the series, and the adoral is reduced in size, the aboral becoming conspicuous and equaling the furrow spinelets in length. The outer margin of the plate is occupied proximally by an irregular row of three to six bluntly pointed granules; distally there are two rows or a group. The adambulacral plates, far along furrow, gradually become square.

Mouth plates large, rather plane, with a long margin to furrow bordered by about ten spinelets, increasing slightly in size toward the inner angle, the innermost spine being strongly compressed and leaf-like, and those adjacent three-sided in section. About eight shorter, blunt, irregular, tubercular spinelets form a parallel series which is continued along the first adambulacral margin. On the outer part of the plate three or four elongated granules stand close to the median suture (which is not visible), and the series of spinelets just mentioned may be continuous with these instead of with the spinelets standing on margin adjacent to adambulacral.

Actinal intermediate plates numerous, but the sutures are not readily seen. The series of plates adjacent to adambulacrals are not larger than the next series, are obliquely elliptical in general form, but have several sides. The other plates are elliptical or irregularly rhombic, sometimes roundish. They have not the straight-cut sides found in *granularis*, *japonicus*, and *patagonicus*. In the previously mentioned young specimen from southern California the plates are much more regular; it is possible that the irregularity comes with age. The plates bear spaced, large, hemispherical granules, those occupying the margin being sensibly smaller and more or less pointed. Many of the plates adjacent to the adambulacrals bear a conspicuous pedicellaria, with two oblong, slightly spatulate, round-tipped, or subtruncate jaws. Near the margin many plates have a similar but smaller pedicellaria with two or three jaws. The granulation is much coarser than in *leptoceramus*, where the granules are also spaced and uniform in size.

Madreporic body circular, convex, situated one-third minor radius from center of disk; striations interrupted and meandering.

Young.—The specimen from station 4407 has R about 28 mm. and r 18 mm. It may be an extreme variant of *C. leptocerama*, but differs markedly from that form in the spaced marginal granules and the enlarged actinal spinelets of the adambulacral plates. The granulation of the actinal intermediate plates is like that of *clarki*, but the plates are more regular in form. The abactinal paxilliform plates are essentially like the type, but have fewer granules.

Type.—Cat. No. 27883, U.S.N.M.

Type-locality.—*Albatross* station 4772, Bowers Bank, Bering Sea (lat. 54° 30′ 30″ N.; long. 179° 14′ E.) 344 fathoms, greenish-brown sand, one specimen.

Distribution.—Southern Bering Sea to southern California, and from 334 to 600 fathoms.

Specimens examined.—The type, and an immature specimen from station 4407, between San Clemente and Santa Catalina islands, California, 334 to 600 fathoms, rocks, shells, fine gray sand. The latter was in company with *C. leptoceramus*.

Remarks.—This species is characterized by the small marginals, with coarse spaced granulation, by the coarse spaced actinal granulation, by the armature of the adambulacral plates, and by the rather small abactinal paxilliform ornate tabula. The species differs from *C. leptoceramus* in lacking secondary abactinal plates, in having coarser actinal and marginal granules, much coarser and fewer abactinal granules to each plate, fewer and longer furrow spinelets, and in having the first series of the actinal adambulacral spinelets well developed and tubercular. From *C. japonicus*, *clarki* differs in all these points; especially striking are the differences in abactinal and actinal granulation and in the form and armature of the adambulacral plates.

Unfortunately there is only one undoubted specimen of this somewhat aberrant species. It is aberrant in that it departs distinctly from the type facies of the genus (as exhibited by *C. granularis* and *C. patagonicus*) and shows a tendency toward *Mediaster*. *C. japonicus* and *C. leptoceramus* are similarly aberrant in a slightly different direction, possibly also toward *Mediaster*. *Mediaster*, *Nymphaster*, and *Nereidaster* are closely related and the gap between them and such genera as *Goniaster*, *Pentagonaster*, *Tosia*, *Peltaster*, *Eugoniaster*, and *Plinthaster* is bridged by the various species of *Ceramaster*. So it does not appear possible to separate the groups into two subfamilies, although the extremes, such genera as *Mediaster* or *Nymphaster* on the one hand and *Goniaster* or *Pentagonaster* on the other, are strikingly different.

Named for Dr. Hubert Lyman Clark.

CERAMASTER ARCTICUS (Verrill).

Pl. 40, figs. 1, 2; pl. 58, fig. 1; pl. 60, fig. 1.

Tosia arctica VERRILL, Amer. Journ. Sci., vol. 28, July, 1909, p. 63, figs. 8, 8*a*.

Diagnosis.—Arcuate pentagonal; R = 55 mm.; r = 34 mm.; R = 1.6 r (also 1.5 r). The short rays, or corners of disk, bluntly rounded. Marginal plates forming an evenly rounded margin to disk, massive, with usually a slightly tumid bare spot, and with large flat crowded polygonal granules; bare spot sometimes lacking on all but distal plates; either the penultimate or the last two superomarginals in contact medially, terminal plate large, ovoid, usually separating the last superomarginals of either side. All abactinal plates with very strongly stellate bases, and all with stout, low tabula bearing, as a rule four to twelve large overhanging, crowded triangular, quadrate, or pentagonal marginal granules, frequently surrounding one to three smaller polygonal granules; often no central granules; the crown of granules circular or more often irregularly polygonal and resembling, with tabula, a miniature toadstool; primary apical plates, and also sometimes others in center of disk, with numerous central granules. Actinal intermediate plates with unequal, large triangular, trapeziform, square and polygonal, very slightly spaced nearly flat-topped granules; plates quadrate with usually a rhomboidal form. Adambulacral plates short and wide, transversely oblong in form, with a furrow series of usually two, less commonly three, short swollen, blunt, frequently compressed upright spinelets, which do not extend much if any above the general surface of the actinal granulation. Actinal surface with three to six granules, one of which immediately behind the furrow series is larger than rest; frequently an upright bivalved pedicellaria with oblong, truncate or round-tipped jaws stands among the granules, above which it does not extend.

Description.—The abactinal paxilliform plates are very characteristic in their armature. The granules are slightly convex, and the marginal series overhang so that from the side a paxilla has the form of a miniature toadstool. The granules are large, few in number, and frequently the central granules are lacking. Superficially the tabula bear a great resemblance to Sladen's figure of *Gnathaster elongatus*.[a] The outer or free edge of the granules is straight, curved, or angular. The primary basal plates have much smaller and numerous granules so that they are conspicuous among the other plates. In a specimen from the Shumagin Islands a curious coalescence of the granules has taken place on some of the tabula. In one case all but two, in another all but three, and in still another all the granules have fused, leaving no sutures. The latter looks like a nail head. The plates are in fairly regular series parallel with the median radial. No abactinal pedicellariæ.

The papulæ seem to be generally distributed except for a narrow line where the interradial septum meets the abactinal wall. The plates have strongly stellate bases, the development of the lobes being on the side toward the median radial line. Thus most of the plates have two or three lobes only, which impinge upon two or three neighboring plates, as shown by the figures. The great extent of the papular area causes all the plates to have these lobes, which sometimes show sutures at their base, as if on the road to form an independent ossicle.

Superomarginal plates eighteen to twenty-four to a side; inferomarginals, two more. The superomarginals are nearly square in the interbrachial arc, the width being slightly greater than length; distally the width greatly exceeds the length. A little over half the exposed surface is usually bare, except in a large specimen from Bering Island, in which the distal plates have a small bare spot. A single series of large, squarish, close-set granules borders the inner and lateral edges of the bare area, the outer portion of the plate being closely set with large rhomboid, trapeziform, and polygonal granules, those nearest the outer edge being the largest. The inferomarginals are similar to the superomarginals, but the bare spot is smaller.

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[a] *Challenger* Asteroidea, pl. 49, fig. 5.

The adambulacral plates are very short and comparatively broad. The furrow spinelets (two or three in number) are short, thick, sometimes compressed or three-sided in section, and round-tipped. The first actinal series of elongated granules or short spinelets (one or two in number) are thick and intermediate in size between the furrow spinelets and about four angular granules which occupy the outer portion of plate. The two-jawed upright pedicellaria occurs on nearly every plate in a specimen from station 3212 and from Bering Island, but are very few in the Shumagin Island examples, and not numerous in that from Unalaska.

Mouth plates not prominent, the combined pair rhomboid in outline, with straight margins. Armature similar in character to that of adambulacrals. Furrow series, seven or eight; about two series of granules (seven to nine in each) occupy most of the surface of plates.

Madreporic body situated one-third to nearly one-half r from center. Striations interrupted, often in the form of perforations.

Type.—In U.S. National Museum.

Type-locality.—Bering Island (N. Grebnitsky).

Distribution.—From Bering Island along the Aleutians to Kadiak Island, Alaska, low tide to 102 fathoms.

Specimens examined.—Ten, from the following localities:

Specimens of Ceramaster articus examined.

Locality.	Depth.	Collector.	Number.	Collection.
Bering Island, Commander Islands		N. Grebnitsky	1	U. S. Nat. Mus.
Round Island, Coal Harbor, Shumagin Islands	Beach	W. H. Dall	2	Do.
Sanborn Harbor, Shumagin Islands	Lowest water	do	3	Do.
Unalaska and Unga, Aleutian Islands		do	1	Do.
St. Paul, Kadiak, Alaska		W. J. Fisher	2	Do.
Station 3212, off St. Paul, Kadiak	102 fathoms, blue mud.	*Albatross*	1	Do.

Remarks.—This species is characterized by the few large granules of the abactinal tabulate plates, the central granules being often lacking; by the very extensive papular areas, comprising practically the whole of the abactinal surface; by the imbricating abactinal plates which are strongly lobed on one side only; by the short and comparatively wide adambulacral plates which have only two or three thickened furrow spinelets.

Genus CLADASTER Verrill.

Cladaster VERRILL, Trans. Conn. Acad., vol. 10, 1899, p. 175, pl. 28, figs. 2, 2*a*-2*c*. Type, *C. rudis* Verrill.

Diagnosis.—In general appearance most closely resembling *Hippasteria*, but differing in lacking secondary intermediate abactinal plates, prominent marginal tubercles or spines, and abactinal tubercles or spines. Abactinal plates hexagonal or roundish, with spaced granules and sometimes with spatulate pedicellariæ; papulæ single at the rounded corners of the plates; marginal plates large, few, and granular, not increasing in size distad, and without spines or pedicellariæ; actinal interradial areas extensive with rather large angular, roundish or irregular plates bearing spaced equal or unequal granules and spatulate pedicellariæ; adambulacral armature similar to that of *Hippasteria:* two prominent furrow spines, a large heavy subambulacral spine, and several granules.

Remarks.—*Cladaster* is a puzzling genus. Abactinally it reminds one strongly of some form allied to *Tosia*, as it has no prominent spines nor any intermediate secondary plates. But the prominent adambulacral spines are strikingly similar to those of *Hippasteria*. There are, however, no prominent marginal tubercles nor bivalved pedicellariæ, so that the similarity is not maintained to the ambitus. *Cladaster* seems to be unmistakably allied to the Hippasteriinæ, but it lacks what are believed to be important characteristics of that group, the secondary abactinal plates and the tuberculate or spiny marginals.

CLADASTER VALIDUS Fisher.

Pl. 41, figs. 1, 2.

Cladaster validus Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 552.

Diagnosis.—R = 17 mm.; r = 10 mm.; R = 1.7 r. Arcuately pentagonal with slightly convex abactinal surface; broad marginals with tumid naked abactinal surface; regular abactinal plates bearing spaced, deciduous obovoid granules and spatulate pedicellariæ of small size; with two furrow spines and one larger, heavier clavate subambulacral spine; with unequal actinal intermediate granules, and relatively large broadly spatulate pedicellariæ.

Description.—Abactinal plates regularly arranged in series parallel to the medioradial, which fails to attain the terminal plate by the width of two superomarginals; from exterior the abactinal plates appear polygonal with rounded corners, or roundish. Papulæ single, six about each plate (or five interradially), absent only from a small interradial area adjacent to margin. Covering of plates, relatively large obovoid or ovoid well-spaced granules, usually one or two in center and six, eight, or more on periphery; some of the larger plates in center of disk have four to seven central granules. Scattered over abactinal surface are about seventeen two-jawed broadly spatulate pedicellariæ which have no depressions into which they fit when open. The jaws are one and a half to twice as high as granules, and have curved ends.

Superomarginals six (or twelve to a side), and subequal except the last, which is very small. They encroach on abactinal area conspicuously, having there a quadrate contour, the proximal ones being nearer square than the distal; abactinal surface of plates tumid and bare, except for a marginal series of spaced granules similar to those of adjacent abactinal plates. Lateral surface of plates is covered with spaced granules similar to latter but much larger.

Inferomarginals seven (or fourteen to side) and similar to superomarginals, except that the actinal surface has a small and less regular bare space. The inner edge of the plates has two rows of granules, where the superomarginals have one, and these are much smaller than granules of lateral surface of plates, the latter being just like the superomarginal granules. Terminal plate tumid and almost globose; naked above, but granular on the distal face.

Actinal intermediate plates with coarse unequal granules, those on the outer or marginal edge being larger than those on the side toward furrow or mouth angle. Center of many of the plates bears a conspicuous two-jawed broadly spatulate pedicellaria, similar to but much larger than the abactinal, or in lieu of this occasionally a granule. The plates without pedicellariæ are, however, smaller, and there is little central space. The enlarged granules are globose, obovoid, ovoid, or thimble-shaped. Pedicellariæ are higher than any of the granules.

Adambulacral plates with two blunt slightly compressed or cylindrical prominent furrow spines which interlock with those across the narrow furrow, and behind them a slightly longer but much heavier clavate, often swollen-tipped spine with a small (adoral) companion granule. The tip of the subambulacral spine is often obliquely dressed or bent toward furrow. Outer edge of plate has three or two granules larger than those immediately adjacent on actinal intermediate plates.

Mouth plates with five furrow spines, of which the innermost is largest and most compressed, and a large suboral situated at about the middle, behind which are three smaller tubercular granules or spinelets, besides which about six unequal granules border the median suture, the innermost being sometimes enlarged and standing in line with the suboral.

Madreporic body small, triangular, with relatively coarse striæ.

Type.—Cat. No. 27884, U.S.N.M.

Type-locality.—*Albatross* station 3480, Amukta Pass, Aleutian Islands (lat. 52° 06′ N.; long. 171° 45′ W.), 283 fathoms, black sand, coral, rocky (one specimen).

Distribution.—Known only from the type-locality.

Remarks.—The only other described species of this genus is the type, *C. rudis*, taken by the *Albatross* off Florida, at station 2415 (30° 44′ N.), 440 fathoms, coarse sand and shells.

C. validus differs from *C. rudis* in having a definite tumid naked area on upper surface of each superomarginal, abactinal pedicellariæ, very unequal actinal intermediate granules of larger size, larger actinal pedicellariæ, and, relatively to the abactinal granules, larger granules on lateral face of marginals. *C. rudis* has more definite rays, the last four marginals being in contact medially, but this may vary with age. The adambulacral spines seem to be relatively larger in *validus*, but it is difficult to be sure of this point without direct comparison of specimens.

The type-specimen is probably young, but there are so many positive characters that it seems worth while to describe the species, especially as the genus is little known.

Subfamily HIPPASTERIINÆ Verrill, 1899.

Hippasteriinæ Verrill, Trans. Conn. Acad., vol. 10, 1899, p. 174.—Fisher, Bull. U. S. Fish Comm., 1903, pt. 3, 1906, p. 1165.

Antheneidæ Perrier, in part, and most authors.

Genus HIPPASTERIA Gray.

Hippasteria Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 279. Type, *H. europæa* Gray = *H. phrygiana* (Parelius).

Diagnosis.—Goniasteridæ with large disk, short rays, bivalved pedicellariæ, one to three elongated thick furrow spines and only one or two similar actinal adambulacral spines; with two sorts of abactinal plates: (1) Large roundish tumid primary plates bearing a central granule, tubercle, spine, or pedicellaria, and a peripheral series of granules, and (2) more numerous small, irregular, crowded intermediate plates which join the larger plates, and bear externally granules, pedicellariæ, and sometimes small spines and tubercles. Marginal plates with one to six tubercular spines, a peripheral series of granules, and occasionally bivalved pedicellariæ; general surface of marginals not covered with granules. Actinal intermediate plates armed with pedicellariæ and various-sized granules and tubercles. The body surface is covered by a skin which, however, usually does not obscure the plates or granules, and is typically only evident by the thin covering of the granules and by wrinkles between the plates; exceptionally it is thick enough to obscure the borders of the plates, which with the granules then appear immersed. Tube feet with heavy sucking disks. No superambulacral plates.

KEY TO THE SPECIES OF HIPPASTERIA HEREIN DESCRIBED.

a^1. Marginal plates well developed, subquadrate, not separated by encroaching abactinal or actinal intermediate plates; granules fairly or quite smooth.
  b^1. With conspicuous abactinal spines and abactinal surface of marginals not smooth and unarmed.
    c^1. Pedicellariæ shorter and higher; dorsal surface very spiny; as a rule no pedicellariæ on marginal plates; actinal pedicellariæ with oblong or subquadrate jaws; actinal intermediate plates not conspicuously tuberculate; abactinal granules in definite marginal series about the plates, abactinal skeleton not fenestrated.......................................*spinosa*, p. 224.
    c^2. Pedicellariæ low, long; a well developed pedicellaria on the proximal superomarginals, and on most of the inferomarginal plates; papulæ conspicuous, bag-like; actinal intermediate plates tuberculate; actinal pedicellariæ very low, long; abactinal granules small conical, scattered, abactinal membrane thick; abactinal skeleton when viewed from inner side honeycombed or fenestrated..*heathi*, p. 231.
  b^2. No abactinal spines or tubercles (or only exceptionally and abnormally present, and then very few); abactinal plates mostly smooth, bordered by a single row of stout granules; marginals with all except lateral surface bare; lateral spines small and unequal, one or two to a plate or absent; adambulacral spines two, clavate, in a transverse series.......................*leiopelta*, p. 227.
a^2. Marginal plates weak, irregular, oval, or elliptical, the proximal usually separated by encroaching plates from the dorsal and ventral surfaces; actinal pedicellariæ high, rather delicate, flaring at base, and with narrow curved serrate tips; granules rugose or denticulate....*californica*, p. 233.

HIPPASTERIA SPINOSA Verrill.

Pl. 42, figs. 1–3; pl. 43, figs. 1, 2; pl. 60, fig. 4.

Hippasteria spinosa VERRILL, Amer. Journ. Sci., vol. 28, July, 1909, p. 63.

Diagnosis.—Similar to *H. phrygiana* of the north Atlantic, but primary abactinal and marginal plates with prominent, often long, tapering blunt spines rather than the elongate tubercles of *phrygiana*.

Description.—Rays five. R = 110 mm.; r = 56 mm.; R = 2 r. Breadth of ray at base, 64 mm. General form same as *phrygiana*, but rays a trifle broader. Majority of the larger or primary abactinal plates convex and bearing in center a stout, upright, rigid, tapering truncate spine, one to two times width of its plate in length; midradial spines slightly the longest, thence decreasing in length to margin of area; same plates in *phrygiana* bearing a very much shorter, stouter tubercle, truncate or rounded at apex. General surface of plates smooth, but rim encircled by a single series of irregular, small, subconical or roundish granules heavily invested with membrane. Many large and smaller plates bear a large central bivalved pedicellaria, the jaws of which are only slightly wider than high; sometimes the two dimensions are equal. These pedicellariæ are usually narrower and higher than those of *phrygiana* and have thinner blades. Distal edge of jaws is slightly curved, either serrate or smooth. Small intermediate plates intercalated between the larger ones bear one to three or four conical skin-covered granules, or a small central spinelet or pedicellaria, surrounded by irregular granules, depending upon size of plate. As in *phrygiana*, the surface of granules is smooth, and the free edge is rounded, or the whole granule may be subconical and pointed.

Marginal plates slightly tumid as in *phrygiana*. Superomarginals sixteen or seventeen to ray, corresponding with inferomarginals except on distal part of ray. Plates of both series surrounded by a single row of squarish blunt or flattened skin-covered granules, which in one specimen are more pinched with rounded top. Proximal eight or nine plates of each series with two (less commonly only one, or as many as three) rigid spines, similar to abactinal spines, but usually a little larger; remainder of plates with one such spine. In *phrygiana* marginal plates have only robust tubercles. Occasionally a two-jawed pedicellaria occurs on marginal plates, but widely scattered along the series.

Actinal intermediate plates arranged as in *phrygiana*, but pedicellariæ with higher jaws which sometimes taper to a narrow tip; these pedicellariæ frequently have serrate jaws, especially in southern examples. Granules pointed, thickly covered with membrane. Tubercles variable, subtruncate, thimble-shaped, or subconical and sharp, especially in southern examples.

Adambulacral spines arranged practically as in *phrygiana*, but longer and stouter. Actinal spine at least as long as width of plate and subequal to but much stouter than the two furrow spines, which are slightly tapering and compressed at tip. Frequently a pedicellaria stands on the plate.

Mouth plates with four or five furrow spines slightly larger than those of adambulacral plates.

Color in life.—A specimen from off Point Pinos, California, was bright scarlet vermilion when taken from the water; this color disappeared almost at once in alcohol.

Anatomical notes.—No rudimentary superambulacral plates. Intestinal cæcum large, composed of about four radiating branches which immediately subdivide irregularly into numerous slender tubes reaching nearly to margin. Gonad, a thick tuft of branching tubules on either side of the interradial septum, about one-third r from margin. Stomach capacious, the thick hepatic cœca reaching into ray about one-half R.

Variations.—The chief variations concern the length of the abactinal spines and the height of the pedicellariæ. A specimen from station 4292, vicinity of Kadiak Island, and three from station 3080, coast of Washington, have considerably shorter abactinal spines than all the others, but they differ still from typical *phrygiana* in having prominent marginal spines, longer adambulacral spines, and higher pedicellariæ. The actinal pedicellariæ are the most variable, in some cases tending toward the form characteristic of *californica*. The jaws have either smooth or serrate edges.

In Californian specimens the spines are all very prominent, more so than in the northern examples, and the actinal pedicellariæ are plainly serrate. The Monterey Bay (station 4552) example has more numerous marginal spines than the example from off southern California (station 3664). In both, the rays are notably stouter and shorter than in typical *phrygiana*. The specimen from station 4552 has the following characters: R = 71 mm.; r = 40 mm.; R = 1.75 r. Breadth of ray at base, 48 mm. Height of longest abactinal spines, 6 mm. Disk very rigid, marginal plates massive, the upper with proximally two or three spines as long as those of abactinal plates, distally with one or two; more of the inferomarginals have three spines, occasionally four. Marginal spines of both series stand in line, forming a perpendicular series of six in interradial arc (sometimes seven), then five, four, three, and finally two. Pedicellariæ numerous, the jaws slightly wider than high; actinal a trifle higher than abactinal; none on marginal plates. Actinal intermediate plates with short subconical spines forming a group of four or five (in addition to the granules), or they may surround the pedicellaria when that is present. They are equal to or only slightly higher than pedicellariæ. All granules skin-covered, depressed or conical, but not denticulate or rugose as in *H. californica*. Color in life, a bright scarlet vermilion.

Type-locality.—Departure Bay, British Columbia, 18 fathoms.

Distribution.—From southern California to Alaska (Kadiak Island) in 27 to 121 fathoms.

Specimens examined.—Eighteen specimens from the following stations:

Specimens of Hippasteria spinosa examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2872	Off Cape Flattery, Washington	38	gray sand	1	U. S. Nat. Mus.
2874	do	27	rocks and shells	1	Do.
3059	Off Siletz Bay, Oregon	77	mud	1	Do.
3060	Off Tillamook Rock, Oregon	28	brown mud	1	Do.
3080	Off Heceta Bank, Oregon	93	green mud	4	Do.
3445	Straits of Fuca, Wasbington	100	rocky	1	Do.
3500	South of St. George Island, Bering Sea	121	fine gray sand	1	Do.
3664	Near Santa Catalina Island, California	80	do	1	Do.
4233	Near Yes Bay, Behm Canal, Alaska	39–45	soft gray mud	2	*Albatross*, 1903.
4243	Kasaan Bay, Prince of Wales Island, Alaska	42–47	green mud	2	Do.
4292	Shelikof Strait, near Kadiak Island, Alaska	66	gray mud	1	Do.
4295	Shelikof Strait	92	soft gray mud	1	Do.
4552	Off Point Pinos, Monterey Bay, California	73–66	green mud, rocks	1	*Albatross*, 1904.

HIPPASTERIA SPINOSA KURILENSIS, new subspecies.

Pl. 43, fig. 2; pl. 121, fig. 1.

Diagnosis.—Similar to *H. spinosa*, but with shorter rays, and relatively larger pedicellariæ; abactinal granules typically pointed; margin massive, spinous; small pincer-shaped marginal pedicellariæ; adambulacral plates with two unequal compressed furrow spines or only one; one prominent subambulacral spine shorter than the longer furrow spine. R = 55 mm.; r = 32 mm.; R = 1.7 r.

Description.—Abactinal surface spiny, the prominent spines being more conical and pointed than in typical *spinosa*, where the spines are usually subcylindrical with a blunt or truncate tip. Granules in a single series surrounding plates and ending in an abrupt usually sharp point, instead of being rounded. Abactinal pedicellariæ, numerous, large, as high or higher than broad, and wider at top than at base; edge of jaw undulating or slightly denticulate. Papulæ numerous, all over abactinal surface except a very narrow interradial band. Superomarginals tumid, ten to twelve to each ray, each plate with two, and inferomarginals with one or two stout conical spines, and in addition a single row of pointed marginal granules. Pedicellariæ, higher than wide and with denticulate jaws smaller than those of abactinal surface, are scattered here and there, usually on the lateral face of the plates. Such pedicellariæ do not occur in typical *spinosa*.

Actinal surface with numerous pedicellariæ having higher jaws than in *leiopelta*. A prominent series occurs on the row of intermediate plates adjacent to the adambulacrals. The dimensions of these pedicellariæ are variable in typical *spinosa*. The actinal granules are similar in distribution to those of *spinosa*, but often (though not always) have several points, or only one point, rather than a simple low conical form. They are, therefore, somewhat similar to those of *H. californica*. Many of the plates have one or two low thimble-shaped tubercles in the center, in place of pedicellariæ.

Usually the adoral furrow spine is the shorter of the two, and both are strongly compressed at the blunt tip. The adoral spinelet is sometimes wanting on the outer part, or along most of the ray. Actinal spine shorter than the longer furrow spine and usually compressed at the base in a plane parallel to furrow. The outer part of plate is covered with granules. Mouth spines four, strongly compressed, chisel-shaped; usually but one suboral standing near margin, and in line with the marginal spines.

Type.—Cat. No. 27885, U.S.N.M.

Type-locality.—*Albatross* station 4804, off Simushir, Kuril Islands, 229 fathoms, coarse pebbles, black sand.

Distribution.—Known only from the vicinity of Simushir.

Specimens examined.—Eight; from type locality four, and from station 4803, same locality, depth, and bottom, four. (*Albatross*, 1906.)

Remarks.—This race differs considerably in general appearance from typical *spinosa* of the North American coast, as the photograph of the type-specimen will reveal. The actual differences are not great, however, the most striking being the form of the granules, the marginal pedicellariæ, and adambulacral armature.

Along with these specimens were taken one small and four large examples of *H. leiopelta armata*. Three specimens listed as *kurilensis* are possibly hybrids of this race and the typical form of *kurilensis*.

The differences between *leiopelta* and *kurilensis* are at once apparent on a comparison of figures. The latter has much higher pedicellariæ, heavily spined abactinals and marginals, marginal pedicellariæ, and compressed, rather spatulate furrow spines, not stumpy conical ones. The naked surface of the marginals in *leiopelta* is also quite different from the condition of *kurilensis*.

HIPPASTERIA LEIOPELTA Fisher.

Pl. 46, figs. 1–4; pl. 58, fig. 6.

Hippasteria leiopelta FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 553.

Diagnosis.—Rays five. $R = 30$ mm.; $r = 20$ mm.; $R = 1.5$ r. General form stellato-pentagonal to arcuate pentagonal, the latter being usual for small specimens, which have $R =$ about 1.45 r. The longest-rayed specimen has $R = 31.5$ mm.; $r = 18$ mm.; $R = 1.7+r$. Abactinal plates smooth in the middle surrounded by a single series of granules, and bearing besides occasionally a central granule, rarely a tubercle, and (interradially) here and there a large low bivalved pedicellaria. Marginal plates regular, large, dorsally and ventrally naked except for a peripheral series of granules; a cluster of granules with sometimes a spine or tubercle on outer face; no marginal pedicellariæ; scattered large bivalved actinal pedicellariæ; actinal granules large; adambulacral spines two, large and clavate in a transverse row on plate, the furrow spine slightly the larger.

Description.—Abactinal plates large and small intermingled, the larger or primary plates not arranged in very regular order, the median radial coming nearest to forming a series; and that only on outer part of major radius. Periphery of plates surrounded by a single series of rather large ovate, acorn-shaped, or compressed granules blunt or pointed and of unequal size. The surface of the plate is smooth and flat, but occasionally the center of a primary plate has one or two thimble-shaped granules, those on the radial series very rarely enlarged into short tubercular spines. A specimen more often has no abactinal tubercles, or only one, two, or three. The specimen photographed has more than any other. Scattered over the dorsum chiefly on the interradial areas is a variable number (fifteen to sixty-five) of low bivalved pedicellariæ occupying whole width of plate, the jaws lower than the combined breadth of the two jaws. The flat or very gently convex bare surface of the abactinal plates (except those bearing pedicellariæ or an occasional central granule) is one of the most characteristic features of this species.

Marginal plates conspicuous, encroaching conspicuously upon both surfaces. Superomarginals six to nine; inferomarginals one more. Most of the superomarginals wider than long, the abactinal surface slightly tumid and bare, with a peripheral series of granules similar to those of neighboring abactinal plates but usually more compressed and wider than high. Actinal surface of inferomarginals similar but the naked surface a little larger and less convex and the granules even more regular. Outer face of both series covered with unequal ovoid, subglobose, round-tipped or pointed tubercular granules larger than those of dorsum. The granular surface of superomarginals larger (that is, higher) than is that of inferomarginals; one to four granules are enlarged, and frequently one or less often two are developed into short blunt tubercular spines, the superomarginal spines being the longer. There is great irregularity in the occurrence of these spines which are more numerous, irrespective of age, on some specimens than on others. Near the end of ray there are fewer granules, and the plates frequently bear only the peripheral series and a tubercle with several granules near the aboral edge, or only one to several granules. Terminal plate subglobose fairly large with or without granules and one tubercle.

Actinal interradial plates irregular with large unequal peripheral granules, those on the edge toward marginal plates being largest as a rule. In each interradial area adjacent to adambulacrals are from two to nine long low bivalved pedicellariæ, with an undulating smooth or sparsely serrate edge to jaws. These are longer but not higher than the dorsal pedicellariæ, the largest as a rule being near the base of furrow.

Adambulacral plates with typically one prominent club-shaped furrow spine about as long as width of plate and behind it on the surface of plate another similar but slightly shorter one, with two to five additional granules along outer edge, or outer half of plate. Proximally a small adoral companion furrow spine is sometimes present, or more rarely two equal spines. The first plate may bear a pedicellaria on its surface, in which case there are two furrow and no subambulacral spines, but only the marginal granules. The spines are sometimes not so markedly clavate, but more nearly cylindrical or even slightly tapered.

Mouth plates with three to five spines along furrow margin, continued to outer end by three or four granules; several granules and sometimes a tubercular spinelet stand along the suture margin.

All the abactinal, marginal, and actinal spines and granules are immersed in a thin membrane which is not at all apparent on the surface of the plates and does not in any way obscure the outlines of plates. This disappears when specimens are dried.

Madreporic body small, midway between center of disk and inner edge of marginals; striations few, coarse, and radiating.

Color in life, vermilion or orange vermilion apparently, as specimens when received were so tinted.

Anatomical notes.—Intestinal cœcum large, consisting of three principal slightly lobed divisions lying in the trivium and a short lobe lying in the left bivium radius. Gonad in an interradial tuft on either side of membranous interbrachial partition.

An examination of the dorsal plates from the inner or cœlomic surface shows that they are similar in arrangement to those of *H. spinosa* and are fitted together even more closely. The larger and smaller plates are everywhere intermingled, but on outer part of ray the secondary plates form more definite connecting pieces between the primary plates. The large primary plates are polygonal with blunt corners or irregular, the secondary plates are elongate to roundish. Papulæ single and everywhere except a small interradial area near border. Inner surface of skeleton fairly even, without the honeycombed structure of *H. heathi.*

Type.—Cat. No. 27886, U.S.N.M.

Type-locality.—*Albatross* station 4795, off Kamchatka, south of Petropavlovsk (lat. 52° 46′ 50″ N.; long. 158° 44′ 30″ E.), 69 to 48 fathoms, green sand, pebbles.

Distribution.—Sea of Okhotsk to southern Bering Sea.

Specimens examined.—Twenty-eight; from type-locality, sixteen; from station 4794, same locality, 58 to 69 fathoms, sand, pebbles, eleven; from station 5024, off eastern coast of Sakhalin, vicinity of Cape Patience, Okhotsk Sea, 67 fathoms, sand, pebbles, one. (*Albatross*, 1906.)

Remarks.—This well-marked species differs from *phrygiana* and allies in the absence of abactinal spines or tubercles, the center of the plates being usually smooth and bare except for an occasional granule or pedicellaria. Likewise, the marginal plates lack the characteristic spines of *phrygiana*, although spines may be present on the lateral face of the plates. The greater part of the surface of the marginals is bare. The adambulacral spines are heavy and reduced to two, forming a transverse series.

HIPPASTERIA LEIOPELTA ARMATA, new subspecies

Pl. 121, fig. 2; pl. 122, figs. 1, 2.

Diagnosis.—Intermediate in general appearance between *leiopelta* and *phrygiana* but nearer the former; differing from *leiopelta* in having one, and sometimes in the interbrachial arcs two, stout rigid conical spines to each marginal plate, and in having much more numerous, and higher, abactinal pedicellariæ; actinal pedicellariæ shorter and higher; adambulacral spines longer, the single furrow spine tapering and blunt, not clavate, as in *leiopelta*. $R = 73$ mm.; $r = 42$ mm.; $R = 1.7 + r$.

Description.—Abactinal plates bear more numerous pedicellariæ than typical *leiopelta*, and the jaws are relatively higher in proportion to the length, about as in *spinosa* and higher than in *phrygiana*. The median radial plates bear a low thimble-shaped tubercle, scarcely higher and often lower than width of plate. Many of the other abactinal plates bear one or two central granules which may become enlarged into a low tubercle, never conspicuous. In *leiopelta* such tubercles occur only rarely or are entirely absent, the surface of the plate being smooth. A single series of smooth granules surrounds each plate. Papulæ, as in *leiopelta*, all over abactinal surface except a narrow interradial line.

Marginal plates more tumid than in *leiopelta*. On the lateral face on a raised boss is a stout conical rigid spine, and sometimes in the interbrachial arc a second occurs in a transverse line. However, most of the abactinal surface of the superomarginals and the corresponding face of the inferomarginal is bare. Scattered bivalved pedicellariæ smaller than those of abactinal plates also occur in the interbrachial arc. These are not present in *leiopelta*.

The actinal pedicellariæ are shorter and higher than in *leiopelta*, as well as much more numerous. In *leiopelta* the pedicellariæ have the appearance of being immersed in the granulation, while in *armata* they stand well above it (as in *spinosa*). The adambulacral spines (one furrow and one actinal) are longer and relatively slenderer than in *leiopelta* and taper slightly to a very blunt tip. In *leiopelta* they are thick and often clavate. The actinal spine is the shorter. Occasionally an adoral spinelet is present on the furrow series, or merely a granule. Irregular granules cover the remainder of the plate.

Type.—Cat. No. 27887, U.S.N.M.

Type-locality.—*Albatross* station 4804, off Simushir, Kuril Islands, 229 fathoms, coarse pebbles, black sand.

Distribution.—Known only from the type-locality.

Specimens examined.—Five; from the type-locality, three; from station 4803, same locality, depth, and bottom, two. (*Albatross*, 1906.)

Remarks.—A small specimen with R 32 mm. and hence about the same size as the type of *leiopelta* has the characters of the race as well marked as the type, with the exception of the marginal pedicellariæ. This shows that *armata* is not simply a fully grown *leiopelta*. (Pl. 122, fig. 1.)

Armata differs from *kurilensis* in lacking the conspicuous abactinal spines and pointed granules, as well as in the armature of the adambulacrals. It differs from typical *phrygiana* in being more pentagonal in shape, with notably shorter rays, in having only one furrow spine, higher pedicellariæ, and more massive marginals bearing pedicellariæ and longer, sharper spines. The unarmed surface of the marginal plates is much more extensive in *armata*.

In some respects *armata* may be considered as an intermediate form between *phrygiana* and *leiopelta*. It is certainly much nearer the latter, however, and perhaps should be ranked as a full species. It shows such obvious resemblances to *leiopelta*, which furthermore exhibits certain characters of *armata* (as, for instance, the marginal spines) in a rudimentary condition, that a subspecific designation is believed to best indicate the relationship.

The relationship between *armata* and *kurilensis* is not clear. They both range together at stations 4803 and 4804, and several specimens of *kurilensis* seem to have an infusion of *armata* blood, as if hybridism had occurred. These intermediates are nearer *kurilensis*, however, and I do not think that they are genuine intergrading forms between *kurilensis* and *armata*. The possibility of *leiopelta* being connected with *spinosa* through this series must be considered, however improbable it may seem from the great difference of the extreme forms. Future exploration will probably tend to multiply rather than lessen the number of species of *Hippasteria* in the North Pacific.

HIPPASTERIA HEATHI Fisher.

Pl. 44, figs. 1, 2; pl. 58, figs. 5, 5*a*; pl. 60, fig. 6.

Hippasteria heathi FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 309.

Diagnosis.—Rays five. R = 78 mm.; r = 39 mm.; R = 2 r. Breadth of ray at base, 42 mm. General form robust; disk large, rays broad, evenly tapered from a wide base to a blunt recurved extremity. Abactinal surface considerably inflated; a well-defined interradial sulcus leading from marginal plates three-fourths of distance to center of disk. Interbrachial arcs wide, shallow. Abactinal surface covered with robust widely spaced conical spines and more numerous large, low, bivalved pedicellariæ; abactinal granules unequal, small, scattered, immersed in a soft membrane that obscures entirely the outlines of plates; abactinal skeleton fenestrated; papulæ all over abactinal surface large; marginal plates small, most of them with a large bivalved pedicellaria, one to four prominent conical spines and unequal conical granules in one or more series about the margin. Adambulacral plates with two stout blunt furrow and two actinal spines. Actinal intermediate areas with unequal, irregular plates bearing large bivalved pedicellariæ and stout tubercular spines and granules.

Description.—Abactinal surface beset with widely spaced, robust, rigid, tapering, upright, bluntly pointed spines, 3.5 or 4 mm. in length; one, or rarely two, to the larger rather widely separated primary plates; the median radial and either adradial series of spines extending to tip of ray, but very irregularly; the other spines too irregularly distributed to form rows. Scattered all over abactinal surface are many sessile, large, low bivalved pedicellariæ with smooth edges to the jaws. These pedicellariæ (which have a base 1.5 to 3.5 mm. in length, a diameter of 1.5 mm., and a height a trifle less than 1 mm.) are more numerous than the conical spines, and are borne on the primary abactinal plates, usually occupying all the elevated surface. A comparatively few small ones are borne on the larger secondary plates. The primary plates are not well defined and circular with a marginal series of granules as in the two preceding species, but are elliptical as a rule (most of the spine-bearing plates are subcircular) and immersed in a soft membrane, from which the spines, pedicellariæ, and elevated portions of the plate emerge. The small unequal, conical, subspherical, and acorn-shaped granules are immersed in this membrane, and are scattered irregularly and rather sparsely over the exposed portions of the plates and intermediate ossicles. On some of the secondary plates a granule assumes the proportions of a small acorn-shaped tubercle.

When the abactinal skeleton is viewed from the inner or cœlomic surface, it presents a very characteristic appearance. The primary plates are connected by irregularly radiating ridges composed of ossicles placed end to end. The bottom of the intermediate ossicles or plates is much compressed, so that the ridges formed by them are narrow. The height of the ossicles causes the enclosed space to appear as a pit, the skeleton assuming a honeycombed or fenestrated appearance. The meshes of this skeleton are further subdivided by a few smaller low trabeculæ near the surface. These separate the papulæ, are incomplete, and do not interfere with the honeycombed structure mentioned above. (See Pl. 60, fig. 6). The papulæ are very conspicuous in the undried state (2 mm. long) and are distributed all over the abactinal surface.

Marginal plates not particularly conspicuous. Superomarginals, fifteen in number from median interradial line, slightly convex, and confined to side of body; first plate larger than the rest, which are rather longer than high except at end of ray, where the reverse is true; upper edge of the series largely obscured by abactinal membrane. Each plate on proximal half of ray (first to fifth or sixth) bears a sessile bivalved pedicellaria and in addition one to four spines like those of the abactinal surface. Edge of plate (excepting usually the upper) is armed with one or two interrupted series of stout conical granules of various sizes. Outer plates of series have a single central spine and marginal granules in one or two irregular series. Inferomarginals corresponding in number to superomarginals and opposite them in proximal third of ray, but alternate on outer part; they encroach somewhat upon the actinal area, the lower margin being obscured on the disk by the membrane covering the general surface of the plates. Nearly all the plates bear a bivalved pedicellaria and, in addition, on the first two plates of the series a circle of four or five spines (like the superomarginal spines) surrounding it, on the rest two or three, which are situated on the aboral side of the plate. There are also on the border of each plate numerous stout conical tubercular granules mixed with small ones, the former occasionally having one or two enlarged into conical spinules, intermediate in size between the spines and larger granules. The pedicellariæ of the marginal plates are exactly like those of the abactinal surface.

Adambulacral armature, consisting of two heavy cylindrical or slightly compressed blunt furrow spines, the adoral a trifle the smaller on outer half of ray; and on actinal surface a transverse series of two similar spines rather more tapered, the outer the shorter, occupying all the exposed surface, the outer spine reduced in size on the first few plates. Margin of plate surrounded by conical granules, one or two on the outer edge larger than the rest.

Mouth plates small, narrow; furrow margin very extensive; furrow spines four, similar to those of adambulacral plates, the innermost slightly longer and most compressed; on actinal surface opposite the outer furrow spine one compressed spine nearly as long, and on the inner part of the plate usually another, considerably shorter, connected with the first by a linear series of several spaced, unequal, conical granules, which are continued beyond the outer spine to the end of the plate, there forming a group rather than a row.

Actinal interradial areas large, three series of intermediate plates extending to the fourth inferomarginal, two to the fifth, and one to the ninth; each of the plates adjacent to the adambulacrals bears a large, sessile, bivalved pedicellaria, 4 mm. in length, similar to those of dorsal surface, placed usually obliquely crosswise. Numerous other interradial plates also have a pedicellaria, usually somewhat smaller. Plates also armed with one or two conical spinules or tubercles standing on the edge, often on either side of the pedicellaria, in line with a peripheral series of large and small hemispherical or acorn-shaped granules. Plates without pedicellariæ bear one or two unequal thimble-shaped spines surrounded by a peripheral series of small granules, with two or three here and there larger than the others. All the actinal interradial spines are shorter than the marginal.

Madreporic body small, circular, situated slightly nearer center than midway to margin; striations fine, ridges rather wide.

Type.—Cat. No. 22338, U.S.N.M.

Type-locality.—*Albatross* station 4239, Clarence Straits, Alaska, 206 to 248 fathoms, coarse sand, rocky. (Cruise of 1903.)

Distribution.—Known only from the type-locality.

Specimen examined.—The unique type.

Remarks.—This species differs from all the preceding, as well as from *phrygiana*, in having the abactinal granules, which are small and more or less conical, scattered over the plates and not arranged in a definite marginal series; by the preponderance of the large low bivalved pedicellariæ over the spines; by the characteristic form of the abactinal skeleton and the soft investing membrane; in having large and numerous marginal pedicellariæ; in the presence of two actinal adambulacral spines instead of one; in having conspicuous stout actinal spinelets. The pedicellariæ on *heathi* are very large and have lower jaws than in any other species of *Hippasteria*. The abactinal spines are also slightly different, being thicker and more conical, and the papulæ are very conspicuous, being distributed all over the abactinal surface. The scattered granules and rather thick soft abactinal membrane make it impossible to distinguish the outlines of the plates, even in the dried condition. No such difficulty is encountered in other species of *Hippasteria*.

HIPPASTERIA CALIFORNICA Fisher.

Pl. 45, figs. 1–4; pl. 60, fig. 5; pl. 111, fig. 1.

Hippasteria californica FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 310.

Diagnosis.—Disk broad; rays broad and rather short, tapering from a broad base to a bluntly pointed extremity; interbrachial arcs very wide, shallow, and rounded; abactinal surface subject to inflation; disk thinner than in *phrygiana*. Abactinal surface spiny, as in *spinosa*, but typically with fewer spines. Marginal plates small, oblong-elliptical, often separated by encroaching abactinal and actinal intermediate plates, typically with one conspicuous spine. Adambulacral plates with one furrow and one actinal spine and, usually, also a broad fairly high serrate pedicellaria. Abactinal pedicellariæ with quadrate rounded serrate jaws, usually wider at tip than base and either wider than high, or the reverse; actinal pedicellariæ with a broad base, tapering abruptly to a narrow, more or less truncate, incurved, serrate margin; jaws usually higher than wide. All granules denticulate, or more or less rugose, as if covered with minute unequal points and confluent knobs. R = about 2r. Type, R = 73 mm.; r = 35 mm.; breadth of ray at base, 40 mm. Another specimen: R = 100 mm.; r = 55 mm.; breadth of ray at base 64 mm.

Description.—Abactinal surface beset with numerous rigid, upright, tapering, sharp, or bluntly pointed spines, which are variable in length and number, but are usually about as long as in *spinosa*[a] (3.5 to 5 mm.). These spines, which are borne on a boss or convexity of the primary abactinal plates, are nearly twice as numerous in some specimens as in the type. There is a median radial series of about twelve to over twenty spines, and on either side of these two to five very irregular longitudinal series of shorter spines. In the especially spiny individuals some of the secondary plates have short spinules. On a few small specimens the spines are all very short. Abactinal pedicellariæ numerous, usually found on the secondary plates, of divers sizes, according to size of plate, typically with broadly spatulate denticulate jaws, which, however, are quite variable in shape. The jaws may be nearly square, or higher than wide, rarely wider than high, strongly curved to truncate at the biting edge. The teeth are also very variable in length. In the type they are conspicuous and slender, but in a specimen from station 4530 (otherwise also not typical) the edges of the jaw are smooth (the actinal pedicellariæ are toothed, however). The spaced granules, which border all the slightly raised plates, instead of being smooth, as in *phrygiana* and *spinosa*, are beset with tiny prominences, giving them a conspicuously rugose or denticulate appearance; in extreme cases multifid. The membrane investing the surface of body is thinner than in *spinosa*, so that even before the specimen is dried the irregularities of the granules are easily detected.

Abactinal skeleton more open than in *spinosa*. The primary plates are roundish or slightly lobed and well separated. The much more numerous, irregularly disposed, trilobed, roundish, oblong, and very unequal secondary plates form a network between the primary plates by touching or overlapping each other. In those specimens with especially weak marginals the abactinal surface is also thinner and weaker. This is caused by the fact that the larger secondary plates are only loosely joined, leaving comparatively wide meshes, in which are very small independent (that is, separate) grain-like ossicles or rudimentary plates. Papulæ numerous, often conspicuous, emerging between the plates singly—that is, a papula is usually separated from its neighbor by an ossicle, sometimes very small. In large specimens the papulæ extend all over the abactinal surface; in smaller specimens there is a small interradial area near margin free from them.

Marginal plates small and rather thin, irregularly oval or elliptical, longer than high, except at end of ray, where the two dimensions are nearly equal. Superomarginals, twelve to seventeen in number from interradial line to extremity of ray, confined entirely to side of body, and rather inconspicuous; very irregular as to shape; successive plates frequently separated by small intermediate encroaching abactinal plates, each plate with a tapering blunt spine articulated rigidly to a central boss and a marginal series of rugose granules, there being also one or two smooth subconical granules on the general surface, occasionally, also, a pedicellaria just beneath the spine. Inferomarginals very similar to superomarginals, of the same number, but not opposite to them; similarly armed; but the pedicellariæ very rare, actinal intermediate plates encroaching and separating most of the proximal inferomarginals. The marginal plates are very characteristic in this species, being remarkably small in most specimens and usually more or less irregular in shape and disposition. In many cases the actinal and abactinal plates are intercalated between a few or many of the marginals. In one extreme case (station 3344) several superomarginals are separated by two abactinal plates in longitudinal series, so that normal superomarginals seem to alternate with two very much smaller ones. In young specimens this encroachment does not take place. A curious variation is presented by a specimen (which is otherwise not typical) from station 4530, where there are several intermarginal plates on each ray. These are simply abactinal plates, around which the marginal plates have grown, inclosing and segregating them, as it were. Exceptionally, the marginal plates bear two or even three spines. One spine is more usual, however, and in a specimen with R = 113 mm., is 4 to 5 mm. long, measured from the general level of the plate. In large specimens pedicellariæ are rare on the marginals.

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[a] In the original description this species was referred to as *phrygiana;* of course *phrygiana*, having short spines or tubercles, is not at all similar to *californica*.

Adambulacral armature, consisting of (1) a single blunt spine, usually considerably compressed and somewhat tapering, situated on the angular furrow margin, with occasionally a shorter similar adoral companion; or, one or two very short spinelets or compressed granules on either side of the single spine; (2) on the actinal surface a more robust, upright, tapering, blunt spine, situated just external to the furrow spine, and just adoral to this there is frequently a medium-sized pedicellaria, one jaw of which is broad serrate and rather deeply scoop-shaped, closing over the other, which is smaller, thicker, and not hollowed out; margins of plates bordered by numerous peculiar rugose granules, the general surface of the plate being covered with the same. There is some variation in the thickness of the spines. In a large specimen from station 3344 these are swollen and blunt, and between the furrow and actinal spine there is usually a large bivalved pedicellaria considerably lower and broader than in the type.

Actinal intermediate areas large, paved with unequal irregularly roundish, polygonal, or elliptical plates, two series of which extend three-fourths the length of ray, and a single series nearly to tip. Most of the plates bear a central high pedicellaria of a peculiar shape, so far as this genus is concerned; jaws rather thin and wide at base, abruptly narrowing into the distal portion, which bends toward the other jaw, and has a truncate serrated edge. This base varies in width, but is commonly one-half to three-fourths as wide as the plate. The pedicellariæ are wider than high to slightly higher than wide. Plates are bordered with a series of rugose or denticulate granules, with several of the same size on general surface, where there are, besides these, a number of considerably larger, smoother, subconical, or cylindrical granules, immersed like the rest in thin membrane. On some specimens these are almost wanting; on others they are prominent and compressed, sometimes subtubercular and thimble-shaped.

Mouth plates prominent actinally; furrow spines five or six, considerably compressed, the inner spines the larger and heavier; on actinal surface an incomplete series of three spines, parallel with the furrow, usually one near the inner angle and one or two near the outer end of the furrow series; remainder of surface covered with rugose granules, often curiously compressed or pinched, with denticulate edges, these forming a row on the median suture margin and another adjacent to first adambulacral plate.

Madreporic body variable in size, ranging in two large equal-sized specimens from 4.5 to 8 mm. in diameter; situated nearly midway between center and margin of disk; striations radiating and often interrupted.

Color in life coral red. A large aberrant specimen from station 4530 was colored as follows: Abactinal surface salmon orange; the marginal plates and actinal surface yellowish buff.

Anatomical notes.—The inner organization is very similar to that of *H. spinosa.* The intestinal cœcum is, however, much smaller, consisting of short-branched radiating, irregular, and unequal tubes. There are five Polian vesicles.

Type.—Cat. No. 22339, U.S.N.M.

Type-locality.—*Albatross* station 4429, off Santa Cruz Island, California, 680 fathoms, green mud, black pebbles, shells.

Distribution.—Southern California to Washington, 266 to 847 fathoms.

Specimens examined.—Twenty from the following stations:

Specimens of Hippasteria californica examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2892	Santa Barbara Channel, California	284	yellow mud	2	U. S. Nat. Mus.
2896	Off Santa Rosa Island, California	376	do	1	Do.
2948	Off Santa Cruz Island, California	266	gray sand, gravel, broken shells	1	Do.
2980	do	603	green mud	1	Do.
3071	Off Sea Lion Rock, Washington	685	do	1	Do.
3104	Off Half Moon Bay, California	391	clay	1	Do.
3112	Off Pigeon Point, central California	296	fine gray sand	1	Do.
3186	Off Point Sur, central California	328	black sand, mud	1	Do.
3344	Off Cape Elizabeth, Washington	831	green mud	1	Do.
3348	Off Point Arena, California	455	fine gray sand	1	Do.
4345?[a]	Off San Diego, California	25	gray sand	1	*Albatross*, 1904.
4427	Off Santa Cruz Island, California	510	black mud	3	Do.
4429	do	680	green mud	3	Do.
4430	do	281	black sand, pebbles	1	Do.
4530	Off Point Pinos, California	847–755	soft gray mud	1	Do.

[a] Probably incorrectly labeled.

Remarks.—This species is remarkable for the small marginal plates and for the shape of the pedicellariæ of the actinal surface. The granules and adambulacral armature are also different from those of *phrygiana* and *spinosa*. The abactinal skeleton is weaker than that of *phrygiana*, but does not present the fenestrated appearance of *heathi*.

The cœlomic cavity of a specimen from station 4429 was nearly filled with a large parasite, the Ascothoracid crustacean *Dendrogaster*, a figure of which is given. (Pl. 111, fig. 1.) This specimen has a very weak dorsal skeleton and the hepatic cœca are small. Many of the abactinal plates are disconnected and independent, a state of affairs which is not found in a normal example.

Genus CRYPTOPELTASTER Fisher.

Cryptopeltaster Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 311. Type, *C. lepidonotus* Fisher.

Diagnosis.—Nearly related to *Hippasteria*, from which it differs in having the whole abactinal surface covered with numerous flat, circular, quadrate, oval, elliptical, triangular, and polygonal granules attached to the plates and secondary intermediate ossicles in such a manner that there is a very narrow free projecting edge which sometimes overlaps the next granule. The primary circular or elliptical abactinal plates are spaced, and the small intermediate ossicles are quite independent and not arranged so as to form connecting pieces, as in *Hippasteria*. Primary abactinal plates with low central spine or tubercular granule, and many with a large low bivalved pedicellaria occupying entire width of plate. Actinal and marginal plates covered with flat large granules similar to those of dorsum, but usually without the free rim. Marginal plates with a central short tubercular spine. Actinal interradial areas extensive, the intermediate plates adjacent to adambulacrals with large bivalved pedicellariæ; the others with one or more enlarged central granules. Adambulacral plates with two heavy furrow spines and one shorter actinal spine, similar in character to those of *Hippasteria*; but, unlike that genus, the furrow series is often replaced by a large bivalved pedicellaria, occupying entire length of furrow margin.

Remarks.—There are three features in which this genus differs from all species of *Hippasteria*—the character of the granulation, the arrangement of the abactinal secondary plates, and the substitution of a large bivalved pedicellaria for the furrow spines on some of the adambulacrals. The last I do not consider as of so great importance as the first and second. In this genus there is no indication of the abactinal membrane which is always more or less evident in *Hippasteria* and in which the granules are immersed. Sometimes this membrane is thick and completely hides the underlying plates (as in *H. heathi*); it always forms a thin coating on the granules. In *Hippasteria* the granules form a border about the larger plates of the abactinal surface as well as surrounding the marginal plates. Even the intermediate plates are defined by a marginal series of granules. In *Cryptopeltaster* the entire surface is covered with flat valve-like granules, and the intermediate ossicles usually bear but one large flat valve, like the flaring head of a nail. It is on the intermediate plates that the free edge of the granule is most evident.

Ludwig (1905, p. 140) has indicated that the disposition of the abactinal secondary intermediate plates of his *pacifica* (which he figures) is not unlike that of *Hippasteria phrygiana*. I have examined the dorsal skeleton of two specimens of the latter species and find that the intermediate plates act as binders or joiners of the primary plates. The character of the dorsal skeleton is the same as in *H. spinosa*, and quite unlike that of *Cryptopeltaster*, where the intermediate plates do not in any way connect the primary dorsal plates.

CRYPTOPELTASTER LEPIDONOTUS Fisher.

Pl. 47, figs. 1, 2; pl. 58, figs. 4, 4*a;* pl. 60, fig. 7.

Cryptopeltaster lepidonotus FISHER, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 311.

Diagnosis.—Rays five. R = 105 mm.; r = 51 mm.; R = 2 (+) r. Breadth of ray at base, between second and third superomarginal, 50 mm. or less, according to degree of inflation of abactinal area. Disk large, rays well developed, tapering to a blunt recurved tip; interbrachial arcs very wide and rounded; abactinal area much inflated on rays and radial areas of disk, also in each interradius adjacent to marginals. Abactinal plates covered with flattened, irregularly quadrate, circular, oval, elliptical, and polygonal granules, with usually more or less projecting, often overlapping, edges. Primary abactinal plates circular or elliptical, well spaced, with many independent, small intermediate ossicles. Primary plates bear low conical spines or large low bivalved pedicellariæ. Marginal and actinal plates completely covered with flat granules; each marginal plate with a single tubercular spine. Adambulacral plates with two thick furrow spines or sometimes a large pedicellaria on the margin, and one similar actinal spine just behind the furrow series.

Description.—Abactinal surface is covered with peculiar, flattened, scale-like granules, which are irregularly quadrate, circular, oval, elliptical, triangular, polygonal, boomerang-shaped, and of several other shapes which defy description, of greatly varying sizes and so closely placed that they often overlap a trifle. They are attached to the larger plates of the skeleton in such a manner that usually a narrow free projecting edge is discernible, or they form the flaring summit of many variously sized ossicles packed between the regular rows of rather widely separated primary plates. There is some variation in the amount which the edge of the granules extend beyond the attachment area. Overlapping of edges is common. The granules covering the intermediate plates are larger than those surrounding the spines and pedicellariæ.

The exposed surface of many granules is raised into a low tubercular eminence. Primary plates superficially marked by a robust, low, conical spine, about the base of which is a series of elongated granules often curiously excavated on the edge, these spines decreasing in size toward edge of disk and end of ray, and grading into broad conical granules in the interradial areas, where the primary plates are small, closely packed, and the secondary ossicles nearly wanting. On the ray is a radial series of spines and on either side three or four parallel series, all low (1.5 mm.), scarcely more than tubercles. Long, low, bivalved pedicellariæ (2.5 to 4 mm. in length) are numerous on the abactinal surface, especially on interradial areas, center of disk, and proximal radial areas. Each is surrounded by a series of quadrilateral granules of various sizes; papulæ numerous, especially on rays, but apparently absent from a very small interradial area adjacent to marginal plates.

The abactinal plates when viewed from the inner or cœlomic side are seen to be either circular or elliptical, there being occasionally an indication of one or more short lobes. They are arranged in spaced, not very regular, longitudinal series and the interspaces are filled with independent, small, very unequal ossicles, the upper ends of which bear large scale-like granules, usually about one (sometimes three or four) to an ossicle. The papulæ are scattered abundantly among these ossicles. The figure will show more clearly the arrangement of the dorsal plates.

Superomarginal plates rather small, irregularly quadrilateral, higher than long in middle of interbrachial arc, but longer than high throughout most of ray except at tip. On account of the inflation of the abactinal surface these plates are mostly confined to side of ray, and the abactinal edge of each is arched. Each plate is tumid and bears in the center a rigid acorn-shaped or conical tubercular spine slightly larger than those of the median radial series. The general surface of plates is covered with polygonal granules similar to those of abactinal surface, the peripheral granules being elongated and a number on each plate convex or low. The granules are attached by nearly the entire under surface, there being very little free edge. Superomarginals twenty-six or twenty-seven in number from median interradial line to extremity of ray. Inferomarginals slightly larger, and more nearly square on the ray where the upper series is oblong. In general each inferomarginal corresponds to a superomarginal and is similarly covered with granules (most of which, exclusive of the peripheral series, are prominent or subconical). Each bears one or two, rarely three, tubercular spines in the center, all short and stubby. Smaller plates intercalated here and there in the inferior series are apparently due to injury of some sort.

Adambulacral plates nearly square, each bearing two large, heavy truncate furrow spines, usually compressed at tip. Sometimes the tip is conspicuously widened and occasionally grooved or even incipiently bifid or trifid. A large sessile bivalved pedicellaria occupies the furrow margin of first plate, extending the whole length of plate; a similar pedicellaria occurs frequently on other plates of the series but there is no regularity of occurrence. On actinal surface of each plate is a robust spine just behind the furrow spines, which it greatly resembles, though a trifle shorter; this spine is either bluntly tipped, compressed, or curiously wrinkled. It is reduced to a small conical tubercle, a mere specialization of one of the granules, on those plates in which a pedicellaria replaces the furrow series. General surface of plate is covered with irregular plate-like granules similar to those of the actinal intermediate plates.

Mouth plates fairly large. Furrow spines three, flattened, the inner flaring and hatchet-like, though irregular; an odd spine at inner angle of the combined plates; one much smaller spine on actinal surface adjacent to outer furrow spine; surface of plate covered with two longitudinal (interradial) rows of flattened plate-like granules which diverge and partially surround the actinal spine, being much smaller toward the inner angle; these granules are quadrate or pentagonal, and their surface sunken a trifle, then raised in a small low boss in the center. The actinal spine may be absent.

Actinal interradial areas large; a single row of intermediate plates extending very nearly to tip; a second series two-thirds the length of the ray; a third very nearly as far; a fourth nearly half, and so on. Plates adjacent to adambulacrals largest, elongated transversely, and more regular than the others, though far from regular themselves; most of them bear a long bivalved sessile pedicellaria (4 mm.) not more than 0.5 mm. high, placed transversely or obliquely transversely, forming a very conspicuous series on either side of the adambulacral plates and extending about half the length of ray. Flat, oblong, or irregular granules surrounding them, the whole being somewhat convex in appearance. A number of the granules have a subconical prominence in the center. The other intermediate plates bear a central conical tubercle, surrounded by several low conical granules which grade into the flatter, plate-like granules toward the periphery of the plate, these granules resembling those of the abactinal surface in shape but not free on the edges.

Madreporic body fairly large, somewhat convex, irregular in outline, situated nearer center than midway to margin; striations deep, irregularly interrupted; anal opening surrounded by a cluster of bead-like granules.

Color in life, scarlet vermilion.

Type.—Cat. No. 22340, U.S.N.M.

Type-locality.—*Albatross* station 4430, off Santa Cruz Island, California, 281 fathoms, black sand, pebbles, rocks.

Distribution.—Known only from the vicinity of Santa Cruz Island, California, but probably extending to the Tres Marias Islands, Mexico. (See below.)

Specimens examined.—The type, and a specimen in the National Museum collection from station 2948, off Santa Cruz Island, California, 266 fathoms, gray sand, gravel, broken shells.

Remarks.—*Hippasteria pacifica* Ludwig (1905, p. 138, figs. 56, 57, 132) is, I believe, the same as *C. lepidonotus*, though in view of some slight differences it may prove to be a geographical variety. It was taken near the Tres Marias Islands (station 3425, 680 fathoms). If the two forms are identical, then the range of *lepidonotus* will be from southern California to the Tres Marias Islands, Mexico.

The differences seem to be as follows: In *pacifica*, more clearly defined abactinal plates, less prominent abactinal tubercles (perhaps due to smaller size of specimen), and less crowded and overlapping abactinal granules. All these differences may be due to the small size of Ludwig's specimen (R=48 mm.). The description of *pacifica* otherwise fits *lepidonotus* very well.

Family LINCKIIDÆ Perrier, 1875.

Ophidiasteridæ[a] VERRILL, Trans. Conn. Acad., vol. 1, pt. 2, 1867, p. 344.

Linckiidæ PERRIER, Révision des Stellérides, 1875, p. 117.—SLADEN, 1889, p. 397 (includes also *Chætaster*).

Linckiadæ VIGUIER, Squelette des Stellérides, 1879, p. 144 (includes *Chætaster*, *Linckia*, and *Nardoa* only).

Phanerozonia with usually small marginal plates, slender, fingerlike rays and small disk; skeleton tessellate; tegumentary developments granulate; superambulacral plates usually present but small; pedicellariæ, when present, foraminate or excavate; papulæ sometimes occurring on actinal surface.

Remarks.—Members of this family are usually found in tropical or subtropical regions. Only one species reaches California. There is no authentic record of either *Pharia* or *Phataria* from the State, although both occur on the coast of Lower California and southward.

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[a] Verrill's name is the oldest, but Linckiidæ has been used by every writer since 1875, and Verrill has himself adopted it. *Ophidiasteridæ* should have received the recognition that was accorded *Echinasteridæ*.

Ludwig (1897) has made *Chætaster* the type of a special family.

KEY TO THE KNOWN GENERA OF LINCKIIDÆ

a^1. Plates simply granulose, or covered with a thick granular or smooth skin, but not spiny.

  b^1. Abactinal plates not forming regular longitudinal series.

    c^1. Adambulacral armature spiniform, often subprismatic, in from one to three series and sometimes resembling that of Goniasterinæ; disk usually well developed, with rays tapering (*Nardoa* frequently with small disk and narrow rays).

      d^1. Papulæ on actinal surface as well as on abactinal.

        e^1. Adambulacral armature in two or more series; papulæ isolated; no superambulacral ossicles; rays flattened.................... *Fromia* Gray.

        e^2. Papulæ in areas; superambulacral ossicles; rays rounded; adambulacral armature in three series.................... *Nardoa* Gray.

      d^2. No papulæ on actinal surface.

        e^1. Adambulacral armature in one series; marginal plates not larger than others; no superambulacral plates.................... *Ferdina* Gray.

        e^2. Adambulacral armature in two or three series (very like the Goniasterinæ); marginal plates conspicuous; rays rather triangular in section; superambulacral plates present. *Narcissia* Gray.

    c^2. Adambulacral armature granuliform in two or three series; rays slender, about same width throughout; disk always small; superambulacral plates.

      d^1. No papulæ on actinal surface; papulæ in areas.

        e^1. Rays more or less cylindrical; papulæ in areas irregularly distributed among the abactinal plates.................... *Linckia* Nardo, p. 242.

        e^2. Rays trigonal; papulæ in one or two continuous uninterrupted rows on either side of ray. *Phataria* Gray.

      d^2. Papulæ single, on both abactinal and actinal surfaces; adambulacral granules in two series, the outer much larger than the inner as in *Ophidiaster*; marginal plates separated near angle of disk by intermediate intermarginals; all plates bossed, separated by granules. *Bunaster* Döderlein.

  b^2. Abactinal plates in regular longitudinal series; adambulacral armature in two, rarely three, unequal series, the outermost largest, sometimes spiniform.

    c^1. Papulæ on actinal surface; superambulacral plates.

      d^1. Plates all granulose; that is, underlying a membrane of variable thickness covered with fine, or coarse, often squamiform granules or papillæ.

        e^1. Papular areas not confluent laterally; madreporic body simple.

          f^1. Between the inferomarginal and adambulacral plates three series of actinal intermediate plates and two series of papular areas; papular areas of the inner series twice as numerous as in the other series.................... *Hacelia* Gray.

          f^2. Only one ventrolateral (actinal intermediate) series of papular areas which are not more numerous than in the other longitudinal series.................... *Ophidiaster* Agassiz.

        e^2. Papular areas confluent laterally; madreporic body large and compound...... *Pharia* Gray.

      d^2. Whole test covered with a thick smooth membranous investment.............. *Leiaster* Peters.

    c^2. No papulæ on actinal surface; superambulacral plates sometimes very small and covered by thick integument.................... *Ophidiaster* Agassiz.

a^2. Abactinal and marginal plates covered with membrane, the former, and occasionally the latter, bearing isolated skin-covered spinelets.................... *Metrodira*[a] Gray.

The above key differs from that of Sladen in the addition of two genera since instituted and in the subordination of the superambulacral plates. These are difficult to find in small specimens, and to base primary divisions on them is likely to cause confusion. Perrier's key (1894) is difficult to work, having the same fault as Sladen's, in addition to ambiguity of expression in Section II A.

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[a] *Scaphaster* de Loriol is a synonym. See Kœhler, Astéries et ophiures des iles Aru et Kei, Abh. Senckenb. Naturf. Ges., vol. 33, 1910, p. 284.

Genus LINCKIA Nardo.

Lin[c]kia Nardo, Oken's Isis, 1834, p. 717. Type, *L. typus* (by designation) =*L. lævigata* (Linnæus).—Gray, Ann. and Mag. Nat. Hist., vol. 6, Dec., 1840, p. 234.

Cribrella Agassiz, Mém. soc. sci. nat. Neuchâtel, vol. 1, 1835, p. 191.

Ophidiaster (part) Müller and Troschel, Monatsber. preuss. Akad. Wiss. Berlin, April, 1840. p. 103.

Acalia Gray (subgenus), Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 285.

Diagnosis.—Linckiidæ with small disk and long cylindrical arms; abactinal plates irregularly disposed, not in regular longitudinal series[a]; papulæ in areas, irregularly scattered, except between the marginal plates; no actinal papulæ; no pedicellariæ; adambulacral armature granuliform in two series.

LINCKIA COLUMBIÆ Gray.

Pl. 48, figs. 1–7.

Linckia columbiæ Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 285; Synopsis, 1866, p. 14.—Sladen, *Challenger* Asteroidea, 1889, p. 784 (Colombia, W. coast).

Linckia ornithopus Verrill, Trans. Conn. Acad., vol. 1, pt. 2, 1867, p. 330.

Linckia diplax Perrier, Révision des Stellérides, 1875, p. 144 (California).

Linckia pacifica, var. *diplax* Sladen, *Challenger* Asteroidea, 1889, p. 786 (California, listed with ??).

Phataria (*Linckia*) *fascialis* Monks, Proc. Acad. Nat. Sci. Phila., vol. 55, 1903, p. 351 (San Pedro, California).

Phataria (*Linckia*) *unifascialis* Gray, var. *bifascialis*, Monks, Proc. Acad. Nat. Sci. Phila., vol. 56, 1904, p. 596.

Diagnosis.—Rays one to nine, usually five; R extremely variable, no two rays ordinarily the same length; R=90 mm.; r=8 mm.; R=11 r; width of ray at base=r. Another average specimen: R=60 mm.; r=6 mm.; R=10 r. (Both measured by longest ray.) Resembling closely *L. guildingii* Gray, from which the species differs in having two instead of three regular lateral rows of plates; in having not more than five prominent abactinal plates on a transverse line across dorsum between the superomarginals (instead of not less than seven in an adult of *guildingii*); in having coarser abactinal granules; in having papular areas noticeably smaller than the primary abactinal plates (larger in *guildingii*).

Description.—The arrangement of plates on ray is as follows: between adambulacrals and inferomarginals three longitudinal series of actinal intermediate plates which are lengthened transversely to ray; then two regular series of marginal plates, irregular or with four or five incipient lobes, the two series being joined by small secondary ossicles; the dorsum between the two series of superomarginals is paved with relatively few large plates with four or five incipient lobes, joined by much smaller irregular oval or somewhat three-sided secondary plates. In a transverse line across the ray between the two series of superomarginals there are from three to five of the larger plates. Thus there are 3+3 actinal intermediates, 2+2 marginal regular series, +3 to 5 irregular abactinals—thirteen to fifteen plates around the arm, omitting the adambulacrals and ambulacrals.

Whole body is covered with rather coarse hemispherical granules, which on the abactinal and lateral surface are fairly uniform in size (being, however, slightly smaller and less uniform in the papular areas), but on the actinal surface are not at all uniform and increasing in size toward the furrow, in the vicinity of which they are larger and often more globose than on the abactinal area. Papular areas small, always smaller than the adjacent slightly convex abactinal plates. There are few pores, usually not more than ten, and commonly as few as three or four. In some examples the granules are not markedly smaller in the papular areas than on the adjacent plates, but usually they are considerably smaller, with numerous very small granules intermixed.

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[a] Except in the decidedly aberrant *Linckia marmorata* (Michelin).

Adambulacral armature nearly identical with that of *L. guildingii.* On the furrow, two granuliform spinelets, the adoral the larger, with a flaring truncate-rounded tip about half as wide as the height; next to this (aborally) a shorter, slenderer spinelet, either slightly tapering and bluntly pointed, or somewhat clavate and truncately rounded. Directly back of the larger spinelet is a tubercular granule more nearly circular (that is, not much compressed) in a transverse section than the furrow granule, round-tipped, and about the same height as the latter.

Madreporic bodies, usually two, sometimes one, or three to five; flat, varying greatly in size, shape, and position. Usually two anal apertures, less commonly one, rarely three or four; rarely two mouths. (Monks.)

Color in life, "mottled reddish brown and ash color, with the tips of the rays and the small new rays, or new portion of the ray a brighter and uniform red." (Monks.)

Variation.—Miss Sarah P. Monks studied this species with reference to the variation and autotomy. She examined over four hundred specimens. The following is quoted from her paper:[a]

> In over 400 specimens examined not more than four were symmetrical, and no two were alike [in regard to the size of the rays]. * * * The animals vary in size from 4 to 17 centimeters. This difference may in some measure be due to age, but there is evidently also considerable difference in size in adult specimens.
>
> The normal number of rays is five, but some specimens have only one, while others have four, six, seven, or even nine; four, five, or six being most common numbers. Of 248 specimens examined 29 had one ray, 34 four rays, 135 five rays, 44 six rays, 5 seven rays, and 1 nine rays.
>
> There is a marked irregularity in the size of the rays, for the breaking and renewing occur at all ages, or at least at all sizes. Single living rays without any external sign of disk are not uncommon. Twenty-two in a lot of 240 were single. In animals measured the rays varied in length from 22–75 mm., and were in all conditions, from specimens which showed by the raw surface that the breakage was recent, through all grades of healing surface to stars where new rays appeared as mere buds, to the comet series and to the various rays of adult Phatariæ [i. e., Linckia].
>
> Comets are frequently found; there were forty-one of them in 240 specimens. These are stars with one long ray and a number of small rays extending from a minute disk. They are rays that have made a new body.
>
> From the great discrepancy in the size of the rays it follows that one or two rays may be sexually mature, while others are small or even buds. In two individuals sexually mature Aug. 4, 1901, the measurements of rays show: male, 77, 70, 58, 20 mm.; female, 70, 65, 52, 13 mm.
>
> There is a great difference in the size of the madreporic body and frequently, but not always, it is larger in large specimens. In 174 specimens 6 had one, 154 had two, 11 had three, 2 had four and 1 had five madreporites.

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[a] Variability and Autotomy of Phataria, Proc. Acad. Nat. Sci. Phila., vol. 56, 1904, p. 596, pl. 42.

The ani are only visible in live animals. In 68 specimens 15 had one, 48 had two, 3 had three, 1 had four ani.

There may be some connection, as has been suggested, between madreporites and breaking plane, but I have failed to find anything satisfactory on the subject. Sometimes the largest ray, or a large ray, is between two madreporic bodies. In 132 specimens 87 long arms and 45 short arms were between madreporites.

I have also found this year (August, 1904) that a *Phataria* may have two mouths.

Type-locality.—"West coast of Colombia" (Gray).

Distribution.—California (Santa Catalina and San Clemente Islands, San Pedro, San Diego) and Lower California (La Paz); Colombia, west coast (Gray); Galapagos Islands (California Academy of Sciences coll.).

Specimens examined.—Forty-one from the following localities:

Specimens of Linckia columbiæ examined.

Locality.	Depth.	Collector.	Number.	Collection.
Santa Catalina Island, California	Shore	W. H. Dall	5	U. S. Nat. Mus.
Do	30 to 40 fathoms	do	1	Do.
Do		S. S. Berry	1	Stanford Univ.
Santa Catalina (Avalon)			2	Univ. of Cal.
La Jolla, San Diego, California			16	Do.
San Clemente Island, California			12	Do.
San Diego, California			1	Mus. of Comp. Zool.
La Paz, Lower California			1	Do.
Galapagos Islands		W. H. Ochsner	2	Cal. Acad. of Sci.

Remarks.—Two questions are suggested: (1) Is this form really distinct from *Linckia guildingii* of the Atlantic and *L. pacifica* of the Pacific? (2) If distinct, is the name chosen the correct one?

I may say at the outset, that with the limited material at my disposal, and from an examination of specimens in the Museum of Comparative Zoölogy, I am unable to find any very satisfactory differences between *L. guildingii*, *L. pacifica*, and *L. diplax*. This opinion is also held by Dr. H. L. Clark. The three forms have been differentiated on the basis of the most variable characters, namely, length of ray and number of madreporic bodies. Perrier says (Révision, p. 143) the only characters which seem to him, after an examination of numerous specimens, to distinguish *diplax* from *pacifica* are: smaller size, slenderer arms, of a number varying from four to seven, and the existence of two madreporic bodies. He says further (p. 147) that he is unable to find any distinctive character between *Linckia guildingii* (from the Atlantic) and a specimen collected at Tahiti. All writers (including myself, 1906) have placed faith upon the number of madreporic bodies, whereas in the present group of species it is worthless for classificatory purposes, as also I think are the proportions and number of rays.

We have to deal in the present connection only with *Linckia guildingii*. It may be assumed that the same characters hold good for "*diplax*." They do for two specimens of very different size in the Stanford Collection. One is young, the other full grown. The following differences hold good for all the specimens I have examined; six *guildingii* from Brazil, Tortugas, St. Kitts, and Florida, and forty-one *columbiæ* from California, Lower California (La Paz), and the Galapagos Islands.

guildingii.	*columbiæ.*
Along side of ray three regular longitudinal rows of plates, clearly distinguishable except in injured arms; then they are distinguishable on distal portion of ray.	Only two regular longitudinal rows of plates along side of ray (superomarginals and inferomarginals).
Abactinal plates numerous; in large specimens, and also in some small ones, the midradial region with conspicuously smaller plates.[a] In a transverse line across dorsum, between superomarginals, one can count in medium-sized individuals ten to twelve primary abactinal plates (rarely so few as seven in small examples).	Abactinal plates fewer; the plates [b] of the midradial region are never conspicuously smaller than the marginals. In a transverse line across dorsum, between superomarginals, one can count in large individuals five primary abactinal plates.
In mature specimens the papular areas of dorsum are larger or equal to the surrounding plates, and the papulæ are fifteen to forty to an area.	In all specimens the papular areas are very much smaller than surrounding plates.
(In young specimens which have not attained their growth the papular areas are naturally smaller than the plates; there is a time when only one pore to an area obtains.)	Papular pores in fully grown specimens eight to twelve or fewer to an area.

The following differences may or not be constant, and are not of so much importance as the above: in *columbiæ* the granules are coarser, especially in the papular areas, and the marginal and abactinal plates show four or five slight lobes. In *guildingii* the plates are more often three-lobed, or roundish. *Columbiæ* is much smaller than *guildingii.*

There is no constant difference in proportions, number of madreporites, number of rays, nor in color. The unreliability of these characters is sufficiently brought out by Miss Monks's notes quoted above.

The question concerning the name is satisfactorily answered by two specimens from Indefatigable Island, Galapagos, collected by Mr. W. H. Ochsner during a recent (1905–1907) expedition under the auspices of the California Academy of Sciences. These specimens, the largest of which has R. 26 mm., agree in all particulars with Californian examples, and exhibit all the differences from *guildingii* detailed above. Although not topotypes, they are from a relatively near locality and make certain the identification of the Californian examples.

L. columbiæ is confined pretty closely to continental shores. Is it not likely that the species may have been derived from ancestors of the present *guildingii* which spread through the "Straits of Panama" in Tertiary times and ranged north and south from that point?

Autotomy.—Three specimens collected by Dr. W. H. Dall show a single arm regenerating the entire animal. In one there is just an indication of three buds, representing future rays; in the others, the buds of four rays are well started; in one of these regeneration is sufficiently advanced so that the beginning of a disk is to be seen. The mouth is developed, but as yet no madreporic bodies. It is evident, therefore, that this species may regenerate an entire animal, in nature, from an arm, when no part of the disk is present. Miss Monks has conducted experiments on this species. The following extracts are from her paper, already cited:

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[a] It is necessary to clean an arm with sodium hypochlorite or caustic potash to make out this point in small specimens.

[b] This means primary plates, not secondary connecting ossicles.

> I have been fortunate in a series of experiments extending to the present time, August, 1904, in having a number of single rays, cut at various places, regenerate the disk and other rays. I cut off rays and in that way the stretching of the pyloric cæca and the consequent loss of time for its withdrawal were avoided and after a number of months the ray had reached the comet stage. In one case two arms started to grow from the place from which one had been cut. * * *
>
> The breaking plane in the skeleton may occur near the disk, from 6 to 12 mm. from the angle of the ray, or at almost any point on the ray. I have never seen a break that was decidedly inside the disk.
>
> The cause of breaking is obscure. * * * If any external force bears a part in breaking the animal, it is probably that the creature is surprised when limp and relaxed, but I am inclined to think that *Phataria* [i. e., *Linckia*] always breaks itself, no matter what may be the impulse. They may break when conditions are changed, sometimes within a few hours after being placed in jars, or a few days, or even not for months. Some never break, but stand all kinds of inconvenience of heat and cold and stagnant water. * * * Whatever may be the stimulus, the animal can and does break of itself.
>
> During the years 1901–1904 I have watched more than fifty starfish disunite. * * * The ordinary method is for the main portion of the starfish to remain fixed and passive with the tube feet set on the side opposite the departing ray, and for this ray to walk slowly away at right angles to the body, to change position, twist, and do all the active labor necessary to the breakage. If there are more rays than are needed to resist the pulling arm, they take a negative part and position. Frequently they hang limp, with their ambulacræ withdrawn.
>
> There seems to be the same coordination in this work as in the walking of Asteroidea, for in the six or eight positions taken during the severing of a ray the larger portion of the star always keeps pulling in a direction opposite that of the parting ray, and not in any, or all, of the four, five, or six directions of radiation.
>
> The skeleton breaks in one of two ways. In one way the ray swells about its midpoint and grows smaller at its proximal portion as it pulls away from the body. In the region of strain the ossicles become separated for a space of about 25 mm., so that the white connective and muscular tissues shine between them till finally, just before parting, they stand out like beads on a network of shiny white floss. There is much more elasticity in the animal at this time than would seem possible in a starfish.
>
> Immediately after the break the ossicles recover their compact position and the two parted edges show a more or less jagged surface. This way is rapid, the body wall being pulled apart in from three to thirty minutes after the arm becomes narrowed.
>
> In the other way of breaking only a small area is affected by the strain, and the breaking place shows from the first as a fracture. There is no narrowing of the ray, no strained surface and no gradual separation of ossicles. A small opening, something like a crack, appears on the dorsal side of the ray, and this increases with an uneven edge till the body wall is parted around the entire ray. The first visible evidence of this kind of division is, either the ray is in a strained position opposite the body or it lops over and hangs limp, letting its weight act as the pulling power. The invariable method in *Phataria* I have watched, after the body breaks, is: The arm walks away; the pyloric cæca are pulled out of the arm, sometimes for 83 mm., and kept very tense; then a break occurs in the tube connecting the pyloric cæca with the stomach; the pyloric cæca are withdrawn into the arm and the small portion of the tube into the body and the arm is free. The parting of the soft tissues is not abrupt, is accomplished by sundering strands thread by thread. The pyloric cæca and tube are wonderfully elastic. Sometimes the tube is stretched till it appears as the finest thread.
>
> After breaking the pyloric cæca coil up, and as they are retracted to their ordinary position an occasional spasmodic jerk is seen in them. Sometimes they are withdrawn immediately, but frequently an arm crawls around for hours, or days, trailing the cæcum till it is withdrawn or falls away.
>
> Probably if the cæca are not taken in within a few hours the muscles lose their elasticity and the cæca decay and drop off. Occasionally these organs are left on the disk, and sometimes the tube is broken in such a manner as to leave them hanging like two coiled trails. After freeing itself the ray crawls up

the glass and remains so for a long time. This is the attitude of a single ray till all, or nearly all, the pyloric cæcum assumes its normal position.

After one arm is separated, or even when it is going, another may break away. I saw one animal try to break the disk apart after having lost two rays. It took many positions, strained the tissues, and worked for hours, but died before the disk was broken.

The results of my observations are: The breaking is automatic and is effected by pulling apart or fracture without strain; there is coordination of parts in producing the separation; the tissues relax at the plane of rupture; this plane may be near the disk or a variable distance from it on the ray; the pyloric cæca are always pulled out and much stretched; the break of the cæcum occurs at the tube connecting the stomach and glandular portion; the pyloric cæcum is generally taken back into the arm; the severed ray may live more than a week, even under adverse circumstances, without signs of regeneration; and, from my experiments extending over a period of three years, I have found that rays cut at various distances from the disk make disks, mouths, and new rays in about six months.

Family ASTEROPIDÆ[a] Fisher, 1908.

Goniasteridæ PERRIER (part), Révision des Stellérides, 1875, p. 280.

Goniasteridæ (part) and *Asterinidæ* (part) VIGUIER, Squelette des Stellérides, 1879.

Gymnasteriadæ PERRIER, Mém. sur les Étoiles de Mer, etc., 1884, pp. 165, 229.

Gymnasteriidæ SLADEN, *Challenger* Asteroidea, 1889, p. 355.—Authors generally except Perrier.

Gymnasteriidæ + *Poraniidæ* PERRIER, Expéd. sci. du *Travailleur* et du *Talisman*, 1894, pp. 163, 327.

Asteropidæ FISHER, Smiths. Misc. Coll. (Quarterly), vol. 52 (No. 1799), 1908, p. 90; Zool. Anz., vol. 32, 1908, p. 358.

Phanerozonia with the test covered by a skin or membrane, either smooth, granulose, or beset with spinelets; marginal plates prominent, more or less overlapping, smooth or with a single spine or several marginal spinelets; abactinal skeleton loosely tessellate or reticulate; actinal plates fairly large, in chevrons or in isolated serial arrangement; papulæ usually in areas never actinal but sometimes intermarginal; pedicellariæ when present bivalved or pincer-shaped.

KEY TO THE KNOWN GENERA OF ASTEROPIDÆ.

a^1. Marginal and abactinal plates devoid of spines.

b^1. Abactinal plates slightly lobed or irregular, tessellated, not forming a reticulum; adambulacral armature: furrow series consisting of two spines; actinal spines one or two; a pair of specially localized pedicellariæ at base of rays on abactinal surface.................. *Petricia*[b] Gray.

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[a] The change of name is necessitated by the fact that *Asterope* supersedes *Gymnasteria*. Although Poraniidæ is in the field it has been used only by Perrier in a restricted sense for *Porania*, *Tylaster*, *Marginaster*, and *Poraniomorpha*, which he regards as belonging to the Spinulosa. To avoid confusion it is better to retain *Asterope* as the type of the family.

[b] *Petricia* as here used replaces *Asteropsis* of authors, but not of Müller and Troschel. The latter, which was published in 1840, and not in the System der Asteriden, 1842, as invariably quoted, has exactly the same signification as Gray's *Gymnasteria* (Dec., 1840), but is in turn antedated by *Asterope* Müller and Troschel, as explained below (next footnote). The Archiv für Naturgeschichte appeared in three parts to each volume. The article Ueber die Gattungen der Asterien (Auszug aus dem Monatsb. preuss. Akad. Wiss. Berlin, April, 1840), in which *Asteropsis* is described, was very probably in the beginning of the third part, which would make the date about September, 1840. The genus is monotypic, and the name cannot therefore be shifted to *Asteropsis vernicina* (Lamarck), as has been done by Perrier (Révision des Stellérides, 1875, p. 282) and authors since. *Asteropsis* is a synonym of *Asterope*, along with *Gymnasteria*. *Asteropsis vernicina* (Lamarck) Perrier becomes *Petricia vernicina*. The genus *Petricia* Gray (Proc. Zool. Soc., pt. 15, 1847, p. 81) has for type *P. punctata* Gray, which equals *Asterias vernicina* Lamarck.

b^2. Abactinal plates forming a composite reticulated meshwork, inclosing large papular areas; adambulacral armature: furrow series consisting of one spine with fleshy knob, and one smaller actinal spine, the latter hidden in a continuous membranous fold parallel to furrow; marginal plates obliquely placed, strongly imbricating, more or less pear-shaped; no localized pedicellariæ, but sometimes granuliform pedicellariæ on papular areas............*Dermasterias* Perrier, p. 248.

a^2. Marginal plates with spines or spinelets.

b^1. Abactinal plates rounded, forming fairly regular longitudinal series; numerous actinal intermediate plates; all plates covered and mostly obscured by thick skin; a medioradial and superomarginal series of spines; superomarginal plates forming the margin and bearing large isolated spines; abactinal plates in a definite medioradial and parallel series; abactinal plates forming also regular transverse series, the medioradial elongated longitudinally, the dorsolaterals elongated transversely (not rounded as stated by Sladen)................*Asterope*[a] Müller and Troschel.

b^2. Abactinal plates not forming regular longitudinal series; no very prominent median radial series as in *Asterope*.

c^1. Abactinal area devoid of plating; actinal intermediate plates forming isolated bands in transverse series..*Tylaster* Danielssen and Koren.

c^2. Abactinal area plated; actinal area with large intermediate plates.

d^1. Plates covered with thick skin, usually devoid of spines, or only rare isolated ones present. *Porania* Gray.

d^2. Plates usually spinous, or with the whole membrane closely crowded with miliary spinelets.

e^1. Inferomarginal plates with a flattened comb of spinelets which form a broad marginal fringe..*Marginaster* Perrier.

e^2. Spines when borne on the marginal plates grouped and inconspicuous, not forming a marginal fringe; papulæ isolated or grouped ....*Poraniomorpha*[b] Danielsson and Koren.

Genus DERMASTERIAS Perrier.

Dermasterias Perrier, Révision des Stellérides, 1875, p. 282. Type, *Dermasterias inermis* Perrier=*Asteropsis imbricata* Grube.

Asteropsis of Authors, previous to 1875, and A. Agassiz, North American Starfishes, 1877, p. 106 (not *Asteropsis* Müller and Troschel).

Diagnosis.—Stellate, with moderately large, obliquely placed, imbricating marginal plates; whole test covered with a thick leathery skin obscuring the plates; no spines except on adambulacral plates; abactinal plates forming a meshwork inclosing large papular areas; papulæ numerous; adambulacral plates with a single furrow spine, and one actinal, the former webbed in a continuous series along furrow, the latter immersed in a continuous parallel fold of thick skin; granuliform abactinal, and valvate adambulacral, pedicellariæ sometimes present.

Only one species known.

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[a] Within the year 1840 *Asterias carinifera* Lamarck was made the type of three genera: *Asterope* Müller and Troschel, *Asteropsis* Müller and Troschel, and *Gymnasteria* Gray. The first was described in April (Monatsb. preuss. Akad. Wiss. Berlin, p. 104), the second in September (Archiv f. Naturgesch., p. 322), and the last in December (Ann. and Mag. Nat. Hist., vol. 6, p. 278). Müller and Troschel thought that their *Asterope* was invalidated by *Asterope* Philippi (for a crustacean), published in June of the same year in Archiv f. Naturg., Heft 2, p. 186, so that they changed the name to *Asteropsis* in their article Ueber die Gattungen der Asterien, published about September in the same journal, p. 322. Investigation proves, however, that Philippi's name was published fully two months after that of Müller and Troschel, the evidence being a reprint of Philippi's article in the Annals and Magazine of Natural History, vol. 6, September, 1840, p. 89. This translation states that it is reprinted from Wiegmann's Archiv, Heft 2, June, 1840, thus fixing the date. There is no reason why *Asterope* should not replace *Gymnasteria*. Sladen was in error.

[b] Includes *Rhegaster* Sladen and *Lasiaster* Sladen. See Grieg, Bergens Museums Aarbog, 1906, No. 13, p. 41.

DERMASTERIAS IMBRICATA (Grube).

Pl. 49, figs. 1-2; pl. 56, fig. 7.

Asteropsis imbricata GRUBE, Archiv f. Naturgesch., 1857, p. 340; Nova Acta Acad. Cæs. Leop. Carol. Nat. Cur., vol. 27, 1857, p. 6, pl. 1, fig. 5 (Sitka).—VERRILL, Trans. Conn. Acad., vol. 1, pt. 2, 1867, p. 324.—A. AGASSIZ, Mem. Mus. Comp. Zoöl., vol. 5, No. 1, 1877, p. 106, pl. 15.

Dermasterias inermis PERRIER, Révision des Stellérides, 1875, p. 282.

Dermasterias imbricata SLADEN, *Challenger* Asteroidea, 1889 (Vancouver Island to San Francisco).—CLARK, Proc. Boston Soc. Nat. Hist., vol. 29, No. 15, 1901, p. 325, pl. 1; pl. 4, figs. 2–4 (Puget Sound).

"*Dermaster*" *imbricatus* J. F. WHITEAVES, Trans. Roy. Soc. Canada, vol. 4, sec. 4, 1886 (1887), p. 117 (Melaspina Inlet, British Columbia and Johnstone Strait, British Columbia).

Diagnosis.—Rays five. R=120 mm.; r=45 mm.; R—2.6+r. Breadth of ray at base, 50 mm. A small specimen: R=55 mm.; r=22 mm.; r=2.5 mm. Breadth of ray at base, 29 mm. Rays rather evenly tapered from broad base to blunt extremity; disk usually fairly high and abactinal surface more or less inflated with interradial depressions; actinal surface flat. Whole animal covered with a thick leathery membrane wholly obscuring the underlying plates, unless dried. No spines except along furrow margin. Membrane contains flattened lime spicules or deposits in the shape of rods or perforated plates. Papulæ in areas, six or eight longitudinal rows on each ray, and upward to twenty-two papulæ to an area; large specimens usually with several (one to nine) small pedicellariæ on each area, consisting of two, three, or four granuliform jaws; pedicellariæ absent from small and some large specimens. Marginal plates smooth, imbricated, numerous, normally wholly obscured by skin. Adambulacral plates with a stout blunt furrow spine tipped with a soft fleshy knob, the whole series along furrow margin being connected by tough skin for about half the length of spines; back of these and separated by a distinct furrow is a parallel ridge of tough skin not quite so high as the furrow spines, containing, for each plate, a flattened ovate or elliptical spinelet; the tips of these spinelets give the ridge a scalloped appearance. In some large specimens, in this furrow, between the two series of spinules, at base of ray are a number of pedicellariæ with one, two, or three flattened ovate or elliptical jaws, much larger than those of abactinal surface. Tube feet stout with large sucking disks, no deposits in wall. Madreporic body flat, sunken in the abactinal skin; striæ fine, branching, radiating from an eccentric point.

Description.—Grube (1857[a]), Agassiz (1877), and Clark (1901) have figured and described this species more or less completely. It will only be necessary, therefore, to enlarge upon certain features, as current descriptions need modification in the light of more abundant material.

The number of papulæ to an area is, of course, very variable, depending chiefly upon the size of the example. The areas are not always in very definite or regular series, but usually are. The pedicellariæ are present in considerable numbers on the abactinal surface of all (seven) the large northern specimens, and also on two medium-sized ones (Naha Bay). Two fairly large examples (Barclay Sound) have only a very few pedicellariæ, and one (Barclay Sound), with R 73 mm., has none. Small examples usually lack pedicellariæ. Specimens from the vicinity of Monterey Bay (one large and numerous medium-sized and small) lack pedicellariæ altogether. The northern specimens, therefore, differ from the southern in usually having, in full-grown examples, numerous abactinal pedicellariæ. The jaws are low, rounded, and granuliform; two and three jaws are commoner than four. The anal opening is surrounded by numerous granuliform spinelets. Barring the small pedicellariæ the surface of the starfish is slick and smooth. The actinal intermediate areas are smooth, therefore, and are seamed with minute lines or wrinkles which have an interradial direction.

The adambulacral plates are very small, wider than long, and no longer than the width of the spine at base. The calcareous part of the furrow spine is tapering and bluntly pointed. The spines are joined by a continuous web and capped by a prominent fleshy knob. The actinal spinelet is shorter (especially near base of ray), flattened, broadly lanceolate, and often appressed to the adjacent actinal intermediate plate, so that, on account of the heavy skin, there appears to be, in such cases, no actual spinelet. Toward extremity of ray the spinelets are upright and form a scalloped edge to the investing membrane. Adambulacral pedicellariæ are not of constant occurrence in northern examples, and have not been found in southern specimens.

The abactinal skeleton is an open meshwork, consisting of rather widely separated scalloped primary plates connected by numerous slightly overlapping elongated ossicles forming narrow bands between the primary plates, as shown by the figure. Agassiz's figure 3, plate 15, American Starfishes, shows this feature well. In his figure 2 the ossicles appear more loosely joined than normally, but the clear description makes the arrangement plain. The spaces between the meshes of the skeleton, occupied chiefly by the papulæ, contain calcareous granules, which on the disk sometimes form short spurs extending from the main trabeculæ. (See Pl. 49, fig. 2, right-hand photograph.)

Anatomical notes.—The intestinal cœcum is a sac with five irregularly lobulated short saccular divisions; aboral division of stomach large; hepatic cœca large, reaching far along ray. Gonads in a thick tuft attached to the calcareous arch of the interradial septa; from the point of attachment a tube (gonoduct) passes upward for a short distance to the aboral surface. No superambulacral plates.

Type-locality.—Sitka (Grube).

Distribution.—Sitka, Alaska, to Monterey Bay, California, low tide and shallow water, rocks.

Specimens examined.—Twenty-two, from the following localities:

Specimens of Dermasterias imbricata examined.

Locality.	Depth.	Collector.	Number.	Collection.
Tongass, southeastern Alaska	Shore	Lieut.-Commander Nichols	1	U. S. Nat. Mus.
Revillagidedo Island, Alaska	do	T. H. Streets	1	Do.
Kasaan Bay, Prince of Wales Island, Alaska	do	do	1	Do.
Naha Bay, Behm Canal, Alaska	do	*Albatross*, 1905	2	Bur. of Fisheries.
Barclay Sound, British Columbia	do	*Albatross*, 1887-88	10	U. S. Nat. Mus.
Puget Sound, Washington	do	Chas. M. Drake	3	Do.
Tacoma, Washington	do	Mrs. W. B. Hare	1	Do.
Kildare, Oregon	do	Oscar C. Sturges	2	Do.
Monterey Bay, California	do	D. S. Jordan	1	Do.

Also numerous specimens in the Stanford collection from Half Moon Bay and Monterey Bay, California.

Remarks.—No other species has been described in this genus, and the genus itself is sharply marked off from its nearest allies, *Petricia* and *Asterope*.

Order SPINULOSA Perrier.

Pedicellariæ rare, never forcipiform; abactinal skeleton reticulate or imbricated, sometimes absent; abactinal spines always present and usually numerous, isolated, in groups, or forming regular fascicules and pseudopaxillæ; marginal plates usually inconspicuous; papulæ dorsal only or also intramarginal and actinal; ambulacral plates not crowded and compressed; actinostome with adambulacral plates prominent; tube feet with well developed sucking disk, and usually biserial; mouth plates medium-sized or large.

This order is poorly defined as regards its limits toward the Phanerozonia, but is sharply separated from the Forcipulata by the absence of the characteristic forcipiform pedicellariæ of the latter. Certain of the Asteropidæ have been regarded at different times by Perrier as a part of the Asterinidæ, or as constituting a separate family, the Poraniidæ. The entire order Velata of Perrier has been merged with the Spinulosa.

The Asteropidæ contain forms which are not very different from the Goniasteridæ and other genera which show decided relationships with the Spinulosa. The family is therefore in a measure transitional. The Ganeriidæ are also somewhat intermediate, but appear to be nearer the Asterinidæ and Echinasteridæ, although the marginal plates are phanerozonid.

The Cryptozonia of Sladen includes, besides the families here assigned to the Spinulosa, all the Forcipulata and the Linckiidæ, and lacks the Ganeriidæ and Asterinidæ, which were relegated to the Phanerozonia. The Linckiidæ are nearer the Goniasteridæ than are the Asterinidæ, but it will probably long be a matter upon which opinion will differ as to whether the Asteropidæ is a natural family. Sladen's arrangement of his cryptozoniate families is certainly unnatural. The placing of the Zoroasteridæ and the Stichasteridæ next to the Linckiidæ and far removed from the Asteriidæ has nothing to recommend it. The Forcipulata is probably the best defined of all the orders, as its families have less in common with the Spinulosa than have those of the Phanerozonia.

If the families constituting the Phanerozonia are first removed, then the Forcipulata segregated, the remainder will be the assemblage constituting the Spinulosa—an order not difficult to recognize but decidedly difficult to adequately characterize.

KEY TO THE KNOWN FAMILIES OF SPINULOSA.

a^1. Mouth plates rather small, not spade-shaped or plowshare-shaped, ambulacral furrows narrow.
  b^1. Marginal plates large and phanerozonid in character; abactinal skeleton imbricated or reticulated actinal plates regularly arranged in rows extending from adambulacrals to marginals and bearing one or two large spines or small groups of spinelets............................*Ganeriidæ* [a]
  b^2. Marginal plates inconspicuous.
    c^1. Abactinal skeleton well developed, not wholly aborted.
      d^1. Abactinal skeleton formed of closely imbricating plates bearing small spines; actinal skeleton formed of imbricating plates bearing a tuft or fan of spinelets............*Asterinidæ*, p. 253.

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[a] Comprises *Ganeria*, *Lebrunaster*, *Cycethra*, *Radiaster*, and *Scotiaster*.

d^2. Abactinal skeleton formed of plates disposed in longitudinal and transverse series forming an irregular or regular mesh work, more or less open, the plates bearing isolated spines or groups of spinelets, but never fans of spinelets.

e^1. Ampullæ single; no pedicellariæ; interbrachial septa weak, more or less rudimentary; abactinal reticulated skeleton irregular, bearing single spinelets, or groups of spinelets, or larger spines..*Echinasteridæ*, p. 258.

e^2. Ampullæ double.

f^1. No pedicellariæ; disk very small; no interbrachial septa; skeletal reticulations roughly in the form of triangles grouped in hexagons; skin, and the large obtuse spines beset with rough scales or spinelets..*Mithrodiidæ*.[a]

f^2. Small two-jawed upright, or large low bivalved pedicellariæ; disk large, interbrachial partitions well developed, with plates; no superficial covering of scales or spinelets over the skin and spines.

g^1. Rays numerous; numerous madreporic bodies; pedicellariæ consisting of two upright tapering jaws arising from a small independent plate; no calcareous rosette in suckers of tube feet; skeleton open reticulate, armed with large isolated spines covered with membrane beset with calcareous granules......................*Acanthasteridæ*.[b]

g^2. Rays five; one madreporic body; large low bivalved pedicellariæ on superomarginal plates, in addition to a few very small upright two-jawed pedicellariæ on the abactinal surface and adambulacral plates; a calcareous reticulum forming a rosette in suckers of tube feet; abactinal plates regularly arranged, leaving small triangular papular spaces, and bearing small isolated spines; actinal intermediate plates bearing one to several large, flat, spinelets..*Valvasteridæ*.[c]

c^2. Abactinal skeleton entirely aborted, only the ambulacral and adambulacral systems remaining. Integument covered with small membrane-enveloped spines...................*Cryasteridæ*.[d]

a^2. Mouth plates large and shaped like a pointed spade or like a plowshare, with conspicuous marginal and usually also suboral spines; furrows wide, adambulacral armature pectinate.

b^1. Marginal plates paxilliform, in either one or two series; abactinal paxillæ never with long spinelets united by membrane but fascicular or penicillate; mouth plates spade-shaped. Actinal intermediate plates present; adambulacral armature in two series at right angles; interbrachial septa..*Solasteridæ*, p. 305.

b^2. Marginal plates either hidden by a supradorsal membrane, or if visible not conspicuous and paxilliform; abactinal plates with spines more or less united by membrane; mouth plates plowshare-shaped (of the type of *Pteraster*); actinal intermediate plates absent or indistinguishable; adambulacral armature in one or two series; interbrachial septa present or rudimentary.

c^1. No supradorsal membrane forming a special nidamental cavity; no segmental pores or papillæ.

d^1. Interbrachial septa partly calcified; adambulacral armature forming with that of inferomarginal plate a single transverse series, never webbed; abactinal skeleton composed of roundish plates, or lobed plates forming a wide mesh....................*Korethrasteridæ*, p. 340.

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[a] Mithrodiinæ Viguier, 1879, p. 128; Mithrodinæ Perrier, 1884, p. 164; Mithrodidæ Perrier, 1894, p. 4; Mithrodiidæ Fisher, 1906, p. 1094. This family contains only one genus, *Mithrodia* Gray, and differs from the Echinasteridæ in having double ampullæ, in lacking interbrachial septa, and in having the entire body, including spines, overlaid with rough granules and squamiform tubercles or spinelets.

[b] This is equivalent to the Acanthasterinæ Sladen, 1889. *Acanthaster* is a very isolated type, the sole survivor of perhaps a once extensive group. The family of which it is the type differs from the Echinasteridæ, restricted, in having double ampullæ, well developed interbrachial septa, numerous madreporic bodies, upright, two-jawed pedicellariæ, and many rays.

[c] This family is equivalent to the Valvasterinæ Viguier, 1878. It differs from the Echinasteridæ in having double ampullæ, bivalved and two-jawed upright pedicellariæ, a regular abactinal skeleton, conspicuous marginals, strong interbrachial septa, and a rosette of calcareous reticulum in the suckers of the tube feet. Kœhler also considers this group of family rank ("Valvastérides," Kœhler, 1910, p. 176).

[d] "Cryastéridées" Kœhler, Expédition antarctique française, Échinodermes, Dec., 1906, p. 24, Genera *Cryaster* Kœhler and *Magdalenaster* Kœhler.

d^2. Interbrachial septa rudimentary, sometimes partly calcified;[a] adambulacral spines delicate, webbed, not associated with inferomarginal spines; abactinal and lateral plates very delicate, imbedded in the integument, bearing groups of delicate short or long spinelets united by a web or imbedded in a sacculus .... *Myxasteridæ*.[b]

c^2. A complete supradorsal membrane present; segmental pores and papillæ; interbrachial septa not calcified;[c] actinolateral spines present .... *Pterasteridæ*, p. 343.

Family ASTERINIDÆ Gray 1840, emended.

Asterinidæ Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 228 (includes *Palmipes*, *Porania*, *Asterina*, *Patiria*, *Socomia*).—Perrier, Révision des Stellérides, 1875, p. 289; Mission scientif Cap Horn, 1891, p. 107 (includes *Porania*, *Ganeria*, and allies); Exp. sci. du *Travailleur* et du *Talisman*, 1894, p. 141.—Sladen, *Challenger* Asteroidea, 1889 (includes Ganeriinæ).—Fisher, 1906 (excludes Anseropodinæ+Tremasterinæ).

Spinulosa with dorsal skeleton formed of imbricating plates bearing small spinelets or granules singly or in groups or tufts; with regular imbricated actinal intermediate plates bearing a few spinelets or granules, sometimes in combs; marginals minute, usually defining ambitus.

KEY TO THE SUBFAMILIES AND KNOWN GENERA OF ASTERINIDÆ.

a^1. Papulæ distributed widely over disk and radial regions; no aperture in each interradius perforating the disk as in keyhole sand-dollars (*Mellita*); abactinal plates externally crescentiform, thick, bearing granules or short spinelets; plates outside papular areas not thin and scale-like, with internal process .... *Asterininæ* Sladen.

b^1. Abactinal plates not imbricated; covered with spines .... *Parasterina*[d] Fisher

b^2. Abactinal plates imbricated throughout the abactinal area, or only in definite regions.

c^1. Rays cylindrical, more or less elongate; disk small; with a definitely and sharply defined band of crescentiform plates along the median areas of the rays .... *Nepanthia* Gray.

c^2. Rays and body flattened; disk large with sharply angular edges.

d^1. Abactinal plates imbricated by three or four fairly regular internal processes or lobes and bearing on exposed more or less crescentiform surface, or on free edge, granules or short spinelets; all abactinal plates subsimilar .... *Asterina* Nardo, p. 254.

d^2. Abactinal plates imbricating only near the margin, the others spaced apart; covered with naked skin .... *Disasterina* Perrier.

a^2. Papulæ confined to comparatively narrow radial band; plates of papular area strongly stellate. imbricating, the others thin, scale-like, strongly imbricating, the internal edge pointed and prolonged downward into a process which meets a similar process from a ventral plate and forms a dorso-ventral supporting pillar for the very thin disk; general form of dorsolateral plates broadly lanceolate .... *Anseropodinæ*[e] Fisher.

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[a] Sladen (1889, p. xlii) and Bell (1892, p. 4) imply that septa are absent. They are present but do not extend far toward center of disk, and contain calcareous plates.

[b] This family includes the Pythonasterinæ with one genus, *Pythonaster* Sladen, and Myxasterinæ with two genera, *Myxaster* Perrier, and the even more remarkable *Asthenactis* Fisher.

[c] The Pterasteridæ are said to lack interbrachial septa. These are present in several species of *Pteraster* (as, for example, *jordani* and *tesselatus*) and in *Hymenaster kœhleri*, but are not calcified. The interbrachial septa of *H. quadrispinosus* have small thin embryonic plates, which are not visible unless the membrane is examined under a microscope. Such a condition will not be readily confused with an ordinary calcareous or partly calcified septum. See Sladen 1889, p. xlii.

[d] This genus is equal to *Patiria* of authors, not of Gray. Gray's *Patiria* is a synonym of *Asterina* Fisher, Smiths. Misc. Coll. (Quarterly), vol. 52, no. 1799, 1908, p. 90; Zool. Anz., 18 Aug., 1908, p. 358.

[e] Bull. U. S. Fish Comm. for 1903, pt. 3, 1906, p. 1087, footnote. I now think it is better to keep the three subfamilies in one family, and segregate *Cycethra*, *Ganeria*, and *Radiaster* as Perrier has done (1894).

b^1. Abactinal plates bearing tufts of spinelets; no membrane or granules; papulæ in a single row on either side of median radial line...*Anseropoda* Nardo.

b^2. Abactinal plates covered with membrane, bearing granules; no tufts of spinelets; papulæ in several rows on each side of the median radial line. (Furrow spinelets two or three, united along ray by granulous membrane; no actinal adambulacral spinelets)............*Stegnaster* Sladen,

a^3. With five interradially placed slits, perforating disk (opening on both surfaces); general form that of *Anseropoda* but thicker; abactinal plates imbricated, with free margin toward center of disk, and forming a somewhat rhombic squamiform tessellation; papulæ in a petaloid radial area, not reaching center of disk..*Tremasterinæ*[a] Sladen.

Interradial slits about as long as width of plate, situated one-fourth r from center, guarded by seven or eight spinelets on each side; ventrally apertures open just behind broad mouth plates; anal opening prominent, guarded by spinelets; on papular areas the adcentral free curved edge of plates provided with four to ten sharp appressed spines covering four or more papulæ and apparently protecting them; papulæ emerging singly under edge of plates; elsewhere abactinal plates without marginal spines but roughened by low granule-like protuberances; actinal intermediate plates armed with slightly flattened spines similar to those of *Valvaster*, about one to a plate; adambulacral plates with a minute spine in furrow (sometimes two), and then in a transverse line two conspicuous spines like those of actinal intermediate plates[b]...............*Tremaster* Verrill.

Genus ASTERINA Nardo.

Asterina Nardo, De Asteriis, Oken's Isis, 1834, p. 716. Type, *Asterias minuta* Olivi=*Asterias gibbosa* Pennant.

Asteriscus Müller and Troschel (part), Monatsber. preuss. Akad. Wiss. Berlin, 1840, p. 140.

Patiria Gray (not Perrier, Sladen, and authors), Ann. and Mag. Nat. Hist., vol. 6, Dec., 1840, p. 290. Type *Patiria* (=*Asterina*) *coccinea* Gray.

Diagnosis.—General form broadly stellate to pentagonal, with large, more or less elevated disk, and sharp angular margins defined by minute regular marginal plates; abactinal plates externally crescentiform, interspersed with granuliform secondary plates, and bearing granules or short spinelets; internally three or four lobed and imbricating; papulæ in areas or single, widely distributed; actinal and adambulacral plates with combs of spinelets sometimes united by web.

This genus, which is in need of a thorough revision, contains about thirty species, some of which have a wide distribution. The genus as a whole is confined to the littoral zone, never occurring at any considerable depth, and is nearly cosmopolitan in tropical and temperate seas.

ASTERINA MINIATA (Brandt).

Pl. 56, figs. 8, 8*a*.; pl. 61, figs. 1–4; pl. 62, figs. 1, 2.

Asterias miniata Brandt, Prodromus, 1835, p. 68 (Sitka).

Asteriscus miniatus Stimpson, Boston Journ. Nat. Hist., vol. 6, 1857, p. 530.

Asterina miniata Perrier.—Sladen, *Challenger* Asteroidea, 1889, p. 774.

Diagnosis.—Rays five (exceptionally six or seven). General form stellate with short broad rays and high, inflated disk; R=67 mm.; r=40 mm.; R=1.7 r; breadth of ray at base, 44 mm.; occasional specimens with R=2 r; interbrachial arcs rounded and wide; tip of rays blunt. Primary abactinal plates crescent-shaped (the concave margin toward center of disk), interspersed with numerous small granuliform ossicles on the intervening papular areas; toward margin of disk and rays papular areas and the secondary ossicles disappear, the primary plates becoming elliptical, then roundish; primary plates arranged in fairly regular series parallel with the median radial, and closely beset with numerous (upwards to forty) small truncate or round-tipped granules which when covered with the natural epidermis are about as high as broad; the secondary ossicles scattered on the papular areas (upward to twenty-five on large areas of rays) bear a paxilliform group of smaller granules (five to twelve); in life and alcoholic specimens the primary plates and intervening ossicles with their granules are closely packed together, leaving room only for the papulæ (upward to twenty to an area on rays) which diminish in number toward margin, disappearing entirely before the marginal plates are reached. Marginal plates about equal, the inferomarginals defining ambitus; superomarginals slightly larger than adjacent abactinals. Actinal intermediate plates in very regular chevrons bearing each a webbed comb of three to five more or less flattened, sometimes chisel-tipped spinelets, somewhat longer than the base line of the series; usually a large comb just back of mouth plates. Adambulacral plates with three partly webbed tapering, membrane-invested furrow spinelets, two longer than near-by actinal spinelets and the adoral member of series usually markedly shorter than rest; on actinal surface (which is raised above furrow margin) is an oblique (sometimes almost transverse) series of three (two to four) stouter chisel-tipped spinelets (webbed at base). Mouth plates large (free margin equal to three succeeding adambulacrals), bearing five marginal partly webbed spinelets graduated to an inner actinal spine, about as large as the tooth. Madreporic body fairly large, with irregular, branching centrifugal striæ.

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[a] *Challenger* Asteroidea, 1889, p. xxxiv.

[b] I examined the type at the Peabody Museum, New Haven, and another specimen in the U. S. National Museum in Washington.

Color in life.—Color extremely variable; some shade of red, clear or mottled with other tints, is common for the abactinal surface. Some of the variations found in specimens from Monterey Bay are listed.

1. Red predominating.

a. Clear vermilion above; below, cadmium yellow or orange near ambitus, shading into light straw yellow; tube feet raw sienna.

b. Carmine above and below.

c. Very dark dull burnt carmine above, Naples yellow below.

d. Above, very dark purplish Indian red, the same actinally.

e. Above, dark purplish Indian red, mottled with orange or with light yellow ochre; light Naples yellow below.

f. Very dark red, shading to grayish green on radii and center of disk.

2. Yellow predominating.

a. Dull light yellow ochre above, sparsely spotted with very dull dark purple; very pale yellow below.

b. Dull fawn color with a few spots of deep red; the same below. Sometimes a single large spot in center of disk.

c. Light yellow ochre, spotted with orange and dark red.

d. Orange above, mottled with slightly darker orange brown; orange encroaching on yellow of actinal surface.

3. Brown and dull greens predominating.

a. Dull dark olive brown above, with dark reddish spots at center of disk; below orange around edge, rest light yellow.

b. Dark reddish brown shading to dark grayish green along radii and center of disk (similar to 1*f*, but browner).

c. Above, pale dull grayish green; the primary plates are greenish white or gray, the papular areas dull grayish green; sparsely spotted with very dark green; papulæ when extended give the surface a brownish cast, leaving the plates in sharp relief. Below, pale straw yellow, darker at edge of disk.

4. Miscellaneous.

a. Above, pale greenish, deep cadmium, and orange, mingled with large irregular spots of very dark olive green on radii and center of disk.

b. Same, but green spotting all over. Even other combinations may be found at Monterey Bay.

Anatomical notes.—Externally the abactinal plates have a crescent form rounded at either end, and the surface is marked by a slight elevation, also of crescent form, which bears the granules. The papular areas, outside the central region of disk, have a convex margin toward edge of ray (corresponding to the concavity of the plate) and the opposite side is sometimes concave. These areas are everywhere broken up by small intermediate ossicles, which encroach onto the border of the primary plates, and form an incomplete irregular network on the areas. Between the secondary ossicles emerge the papulæ. Sometimes two or more of these granuliform ossicles coalesce to form an irregular rod. In the center of the disk the papular areas are much larger than elsewhere, containing more papulæ and more secondary plates, and the primary plates are smaller, except in the case of the "primary apicals," some of which form a pentagonal ring surrounding the apical area. The photograph will show the arrangement and form of the plates, which have been treated with caustic potash and the spines removed.

Viewed from within, the dorso-lateral plates have four lobes by which they imbricate, the carinals are transversely elongated and nearly oblong, and the adradials are elongated transversely but are triangular. (See pl. 56, fig. 8*a*.)

The actinal intermediate plates are very numerous, imbricated, and marked by a slight spiniferous elevation. The inner edge of this elevation or convexity (except on the small peripheral plates) is marked by two to four slight serrations, transverse to the long axis of plate. The serrations are fairly large, but in very low bas-relief (fig. 8, pl. 56), and can be seen only when the plates are thoroughly cleaned. The spinelets are inserted just back of the serrations. The surface of the adambulacral plates has three similar markings, of which the median is largest.

Variations.—Rays usually five, but occasionally six, and rarely seven; one seven-rayed specimen (Monterey Bay) has three madreporic bodies. Sometimes the tip of a ray is bifurcate, each branch having a normal furrow and plating. This species is stellate, but the length of the major radius varies from 1.7 to 2 r; it is apparently never pentagonal, as is commonly the case with *A. pectinifera* (or a variety). The amount of webbing on the actinal spines is variable, as is the apparent thickness of the epidermis (variability perhaps due to fixation). Some combs are free nearly to base, others webbed nearly (but not quite) to tips; all have more or less conspicuous wings or membranous vanes above the webbing. The points of the spinelets are frequently less obviously chisel-shaped than in the figures.

Variations in color, already mentioned, are wide.

Type-locality.—Sitka, Alaska.

Distribution.—Sitka, Alaska, all the way to San Diego, California, in suitable localities, thence to Gulf of California, north of La Paz, Lower California; low tide to 165 fathoms, on rocks, shells, gravel, and hard sand.

Specimens examined.—Eighty, from the following localities:

Specimens of Asterina miniata examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2908	Santa Barbara Channel, California	31	gray sand, broken shells	1	U. S. Nat. Mus.
2914	Cortes Bank, off San Diego, California (long. 119° 3′ W.).	26	broken shells	1	Do.
2940	San Pedro Bay, California (lat. 33° 36′ N.).	26	do	1	Do.
2962	Off Santa Barbara, California	165	sand, stones, coral	2	Do.
2965	do	27	fine gray sand, rocks	1	Do.
2975	Off Anacapa Island, California	36	gravel, broken shells	1	Do.
3001	North of La Paz, Gulf of California.	33	fine gray sand, broken shells.	1	Do.
3131	Monterey Bay, California	48	brown mud, rocks	6	Do.
	Drake's Bay, California	Shore.		1	Do.
	San Francisco, California	Shore.		1	U. S. Nat. Mus., D. S. Jordan.
	do			8	U. S. Nat. Mus., Dr. J. Hornung.
	Monterey Bay, California	(a)		8	U. S. Nat. Mus., *Albatross*, Dall, Jordan.
	San Simeon Bay, California (lat. 35° 38′ N.).	Shore.		2	U. S. Nat. Mus.
	San Diego, California	Shore.		2	U. S. Nat. Mus., Rosa Smith.
	do	Shore.		32	U. S. Nat. Mus., C. R. Orcutt.
	San Pedro, California	Shore.		1	U. S. Nat. Mus., H. N. Lowe.
	Santa Catalina Island, California	Shore.		2	U. S. Nat. Mus., W. H. Dall.
	Gorda, California	Shore.		2	Do.
4563	Near Santa Cruz, California	8	rocks	1	*Albatross*, 1904.
	San Diego, California	(b)		3	Do.
	Clayoquot Sound, British Columbia.	Shore.		3	Stanford, Dr. C. H. Gilbert.

a Shore and 8 fathoms.

b Beacon 3.

Remarks.—This is one of the commonest low-tide species of the California coast, being abundant at San Diego, Monterey Bay, and north of San Francisco Bay. The most favorable situations are sheltered coves where the bottom is covered with fair-sized bowlders and smaller rocks, overgrown with sponges, *Phyllospadix*, coralline, and bryozoans, and where the interspaces are floored with coarse sand, broken shells, and coralline. At low tide the animals are found clinging to the sheltered sides of the rocks, or among *Phyllospadix* and algæ. They are also found abundantly on hard, sandy bottom, as at San Diego.

This species is closely related to *A. pectinifera* (Müller and Troschel) from Japan. The general type of armature is strikingly alike, and the differences are mainly in details of the skeleton and in color. *A. pectinifera* seems to vary more widely than does *miniata*, judging by the specimens in the Stanford University collection. The principal differences are as follows, large specimens being used for comparison:

miniata.	*pectinifera.*
General form stellate with broad rays and curved interbrachial arcs; R=1.7 to 2 r.	General form stellato-pentagonal, to pentagonal with nearly straight sides (Mororan, Hokkaido); R=1.4 r to 1.5 r.
Papular areas large, with about fifteen to twenty pores on proximal radial regions.	Papular areas small; less than fifteen papulæ on proximal radial regions.
Primary abactinal plates rather well spaced with fifteen to twenty-five secondary plates on the intervening meshes of proximal radial region.	Primary abactinal plates more closely placed with fewer (five to fifteen) and relatively larger secondary plates on the papular areas of proximal radial region.
Medioradial (carinal) series of abactinal plates and armature usually fairly regular and conspicuous proximally, the crescents being much larger than adradial series.	Carinal series of abactinal plates and their granules not conspicuously larger than adradials, and not forming a noticeable series (viewed internally they do, however).
Primary groups of abactinal granules of a wide, crescent form, except toward margins, and with many granules (about forty on proximal carinals).	The primary groups of abactinal granules only exceptionally of the wide crescent form (then disk is pentagonal) but generally more elliptical, or bowed elliptical, with fewer granules (about twelve to twenty on proximal carinals).
Spinelets of actinal combs longer than the base line of a comb of four spinelets (much longer than one of three); usually three or four spinelets to a comb.	Spinelets of actinal combs not longer than base line of comb of four. Difference in size of actinal spinelets in the two species more evident on comparison of specimens. Usually five or four,[a] rarely three spinelets to a comb.
Serrate scars on actinal plates larger (difference apparent on comparison).	Serrate scars with fine teeth or bas-relief serrations.
Three furrow and two or three actinal adambulacral spinelets; longest furrow and actinal spinelets equal to or exceeding two adambulacral plates with suture.	Frequently four furrow and four or five[a] actinal adambulacral spinelets; longest actinal and furrow spinelets less than two adambulacral plates with suture.

Family ECHINASTERIDÆ Verrill, restricted.

Echinasteridæ Verrill, Trans. Conn. Acad., vol. 1, pt. 2, 1867, p. 343.—Perrier, 1875, 1884, 1894.—Viguier, 1878.—Sladen, *Challenger*, Asteroidea, 1889, p. 535.

Spinulosa with a reticulate, more or less irregular skeleton formed of small imbricating plates bearing isolated or grouped spines; with biserial tube feet and single ampullæ; suckers of tube feet without rosette of calcareous reticulum; no pedicellariæ. Interbrachial septa weak, more or less rudimentary.

Remarks.—This family, as originally established by Verrill, comprised the genera *Echinaster*, *Acanthaster*, *Mithrodia*, and *Ferdina*. Perrier subsequently (1875) added *Solaster*, *Henricia*, and *Valvaster*, and placed *Ferdina* in the Linckiidæ. Viguier divided the family, in 1878, into four tribes, the Echinasterinæ, Mithrodiinæ, Valvasterinæ, and Solasterinæ. In 1884 Perrier established the family Solasteridæ for *Solaster* and placed *Mithrodia* in a distinct family, which, however, he called "Mithrodinæ." Sladen, 1889, maintained the family Solasteridæ, and placed *Mithrodia* back in the Echinasteridæ, maintaining the subfamilies constituted by Viguier, and establishing a new subfamily, the Acanthasterinæ, for *Acanthaster*.

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[a] These numbers refer to specimens 40 mm. or more major radius.

In this report the genera *Acanthaster*, *Mithrodia*, and *Valvaster* have each been made the type of a distinct family. They have no more in common with the Echinasterinæ of Sladen than have some of the genera of the Solasteridæ; in fact, are more trenchantly separated, I think, than the latter. It is highly probable that the three genera enumerated above are surviving types of once larger groups.

The family Echinasteridæ as limited in this report is therefore coëxtensive with the Echinasterinæ of Sladen's *Challenger* Asteroidea, with the addition of genera since described. The component genera are all included in the subjoined key. They differ from *Acanthaster*, *Mithrodia*, and *Valvaster* in having (so far as known) but one ampulla to each tube foot. The other differences are noted in the key to the families of Spinulosa and accompanying footnotes.

Henricia and *Poraniopsis* are the only genera which occur in the region covered by this report. Clark has recorded *Echinaster tenuispinus* from Puget Sound,[a] but I do not believe his specimens came from that locality. The presence of such forms in his collection as *Arbacia stellata*, *Diadema mexicanum*, *Echinometra oblonga*, *Toxopneustes semituberculatus*, and *Clypeaster rotundus* would at once arouse strong suspicions that two separate lots had in some way become mixed. This is especially the case since the labeling was evidently poor. *Echinaster* or rather *Othilia tenuispina* is from La Paz, Lower California.

KEY TO THE KNOWN GENERA OF ECHINASTERIDÆ.

a^1. Abactinal and lateral skeleton composed of lobed plates connected by intermediate ossicles forming a more or less irregular mesh work.
  b^1. Adambulacral spines or spinelets disposed in transverse series on each plate, or without regularity; not arranged in a regular double longitudinal series.
    c^1. Abactinal plates bearing small spinelets, usually in groups, without a mamelon; usually the skin hiding the plates is not thick and fleshy; the spinelets are never large and isolated; frequently so small as to be granuliform.
      d^1. Actinal papulæ (i. e. between marginal and adambulacral plates); one or more spinelets on furrow face of adambulacral plates.................... *Henricia* Gray, p. 266.
      d^2. No papulæ between marginal and adambulacral plates (that is, none on actinal surface).
        e^1. A sabre shaped spinelet on furrow face of adambulacrals........ *Cribraster*[b] Perrier.
        e^2. No spinelet in furrow.. *Perknaster* Sladen.
    c^2. Abactinal and marginal plates covered with a rather thick skin and bearing simple isolated spines.

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[a] Proc. Bost. Soc. Nat. Hist., vol. 29, 1901, p. 329. (See antea, p. 8.)

[b] I have never seen specimens of either *Cribraster* Perrier or *Perknaster* Sladen and include them here only on the authority of their describers. The generic diagnosis given by Perrier (Stellérides, Cap Horn, 1891, p. 104) would apply to *Henricia sanguinolenta*. In the description of *C. sladeni* however, it is stated that "face ventrale depourvue de papilles respiratoires." The genus is founded upon a single specimen.

Perknaster has been challenged by Bell who calls it "only an aberrant *Echinaster*" (The Echinoderma found off the coast of South Africa. Pt. 2, Asteroidea, p. 253.)

It is worth noting that the distinction used by Perrier in his key to the genera of Echinasteridæ (1894, p. 142), of disk small, *Henricia*, and disk rather large, *Cribroster*, *Perknaster*, will not hold, as *Henricia sanguinolenta eschrichtii* is sometimes nearly pentagonal. Neither does his statement that in *Henricia* the ventro-lateral and marginal plates form series at the same time longitudinal and transverse, always apply, for *Henricia sanguinolenta* constitutes an exception. In this species the character is variable.

d^1. Papular areas very large containing upward to sixty papulæ; spines large, isolated; no small spine in furrow; madreporic body "euplacote," an independent skeletal piece; skin covering the wide meshed skeleton, thick; two adambulacral spines; rays short and swollen .... *Poraniopsis* Perrier, p. 260.

d^2. A small spine in furrow; madreporic body "pseudoplacote" (=the primary interradial or basal plate); meshes of skeleton smaller, and rays frequently long and slender.

e^1. No intermarginal or actinal papulæ.................. *Echinaster* Müller and Troschel.

e^2. Intermarginal and sometimes also actinal papulæ...................... *Othilia* Gray.

b^2. Adambulacral spines arranged in two longitudinal series, but no spinelet deep in furrow; abactinal plates forming wide-meshed network.

c^1. Adambulacral spines in two longitudinal combs of four or five each, disposed in a double longitudinal series along ray. Abactinal plates bearing compact groups of short equal upright spinelets imbedded in a membranous mass................ *Plectaster* Sladen.

c^2. Adambulacral spinelets not in combs.

d^1. One furrow, one actinal spine; actinal intermediate spines; inferomarginal spines single; abactinal spines generally single and large....... *Poraniopsis* Perrier, p. 260.

d^2. Two or three furrow spines; one much larger sometimes bi- or trilobed ligulate spine just behind them; inferomarginal spines three to five, borne on a horizontal lamina; abactinal plates bearing single spines or groups of two or three....................
Dictyaster Alcock and Wood-Mason.

a^2. Abactinal and lateral skeleton composed of quadrilateral plates united at their angles by imbrication. Four adambulacral spinelets along aboral edge of plate; rudimentary spinelet within furrow; actinal intermediate and inferomarginal plates with three or four aboral spines; dorsal surface with very small, short, blunt spines forming irregular longitudinal and transverse rows borne upon edges of plates; ventral and lateral plates connected by an intermediate ossicle; intermediate ossicles occasionally occur between the other plates of skeleton.. *Thyraster* Ives.[a]

Genus PORANIOPSIS Perrier.

Poraniopsis Perrier, Compt. rend., vol. 106, 1888, p. 763 (*nomen nudum*); Mission scientif. Cap Horn, III, Stellérides, 1891, p. 105, pl. 10, fig. 2*a*, 2*b*. Type, *P. echinaster* Perrier (erroneously *P. echinasteroides* on plate, Bay of Nassau, 95 meters).—Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 568.

Lahillea de Loriol, Notes pour servir à l'étude des Échinodermes, sér. 2, fasc. 2, 1904, p. 32, pl. 3, fig. 1, 1*a*–1*g*. Type, *L. mira* P. de Loriol (Gulf of San Mathias, Argentina, low tide).

Alexandraster Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, July 17, 1905, p. 210, pl. 15, figs. 79, 80; pl. 31, figs. 181–183; pl. 32, fig. 184. Type, *A. mirus* Ludwig (Gulf of Panama, 458 fathoms).

Ortmannia de Loriol, Revue critique de paléozoologie, Paris, vol. 10, Jan. 1906, p. 78. Proposed to replace *Lahillea* preoccupied.—Bather, Revue critique de paléozoologie, Paris, vol. 10, 1906, p. 131.

Lahillia de Loriol, Revue critique de paléozoologie, Paris, vol. 10, 1906, p. 77.

Diagnosis.—Echinasteridæ with wide-meshed, reticulate skeleton bearing at the nodes, upright prominent single spines; with large abactinal and intermarginal papular areas (no actinal areas); with two adambulacral spines, but none in furrow (as in *Henricia* and *Echinaster*); whole body overlaid with rather thick skin, mounting the bases of spines, and sometimes investing them; no pedicellariæ; madreporic body an independent plate ("euplacote," Ludwig); tube feet with strong sucking disks and single ampullæ.

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[a] *Thyraster* Ives, type *Echinaster serpentarius* Müller and Troschel. Echinoderms from the northern coast of Yucatan and the harbor of Vera Cruz. Proc. Acad. Nat. Sci. Phila., 1890, p. 329, pl. 8, figs. 19, 20, 21.

KEY TO THE SPECIES OF PORANIOPSIS HEREIN DESCRIBED.

Adambulacral spines with a groove; rays rigid and skeleton stout; adradial row of intermediate ossicles always present .... *inflata.*
Adambulacral spines tapering without a groove; rays weak and flexible; adradial series of intermediate ossicles sometimes absent .... *flexilis.*

Remarks.—This genus differs from *Echinaster* in lacking a spinelet on the furrow face of the adambulacral, and in having the madreporic body an independent plate. The skeleton is very much more open than in either *Echinaster* or *Othilia*, the reticulations being comparatively few and large. Ludwig (1905, p. 210) mentions as another difference from *Echinaster* the presence of intermarginal papular areas, but this will not hold unless *Othilia* is recognized as independent, since *Echinaster sentus, spinosus,* and *spinulosus* have intermarginal papulæ, and *spinulosus* has actinal papulæ. The type of *Othilia* is *Asterias spinosa* Retzius, 1805 (*Echinaster spinosus* Müller and Troschel, 1842) Brazil.

I think a comparison of descriptions and figures will convince any one that Perrier's *Poraniopsis,* de Loriol's *Lahillea,* and Ludwig's *Alexandraster* are the same genus. At any rate there are absolutely no differences of generic importance, *Alexandraster mirus* being even specifically close to *Poraniopsis echinaster.* Perrier's comparison of *Poraniopsis* with *Porania* is certainly misleading for the resemblance is most superficial. The name, *Poraniopsis mira* (de Loriol, 1904) invalidates *P. mira* (Ludwig, 1905). The latter is doubtfully distinct from my *flexilis.*

I did not see de Loriol's paper until after I described "*Alexandraster*" *inflatus* (June 1906) when the identity of the two genera became evident at once. De Loriol published several good figures. A further search brought to light *Poraniopsis,* which so far as I know is the oldest name.

PORANIOPSIS INFLATA (Fisher).

Pl. 58, figs. 7, 7*a;* pl. 63, figs. 1, 2; pl. 112, fig. 1.

Alexandraster inflatus FISHER, Zool. Anz., vol. 30, June 19, 1906, p. 300.
Poraniopsis inflata FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 569.

Diagnosis.—Rays short, robust, evenly tapered or slightly inflated at middle, bluntly pointed; disk capable of considerable inflation; whole animal appearing inflated and turgid. Type, R = 60 mm.; r = 23 mm.; R = 2.6 r; breadth of ray at base, 27 mm. Skeleton forming large squarish or polygonal areas (occupied by very numerous papulæ), the whole covered by a rather thick skin mounting the base of the upright, usually sharp, prominent spines which stand at the corners of the papular areas; counting around the ray from inferomarginal to inferomarginal series inclusive there are seven more or less regular longitudinal rows of spines in type but as many as thirteen in a few large specimens, the extra spines being shorter and forming rows interpolated between the primary series; adambulacral plates with two prominent grooved spines in a transverse series; actinal intermediate spines, often grooved; no actinal papulæ.

Description.—Abactinal and lateral skeleton composed of three or four lobed primary plates connected by several elliptical oblong overlapping ossicles forming a large mesh, inclosing spacious subquadrate and irregular papular spaces, which contain on the disk of large specimens about fifty to sixty-five conspicuous papulæ, these decreasing gradually on the rays to about thirty, then fifteen, then ten; smaller specimens with fewer papulæ. No papulæ on actinal surface. Skin rather thick, obscuring the outlines of plates which form narrow raised ridges, the isolated spines occurring on the larger raised primary plates, usually at a point where three or four ridges join; in other words at corners of papular areas. The spines are borne on a slightly raised boss of plate, boss and spine together being 3 to 6 mm. in length. Spines stout, tapering, usually rather sharp, in small specimens being arranged in a mid-radial, superomarginal and inferomarginal series, with a row of scattered adradials and one of actinal intermediate smaller spines. There is also a large primary basal spine in each interradius and a large central spine. The primary "radials" and "basals" are connected by a ridge so as to form a pentagon, the corners radial. Within this apical area is another more stellate pentagon with the primary basals for corners and the infra-basals for interadii. Connecting the infra-basals with the central plate are five straight ridges, which also form interradial lines to the inner pentagon. The infra-basals have short spines and occasionally one of the ridges radiating from the central plate is missing. These ridges are of course radial with reference to ray, since the points of the inner pentagon are interradial. In mature specimens this regular arrangement is more or less disturbed, although the two pentagons, one within the other, can be readily recognized in the apical region. In large specimens the radial series of spines is usually irregular. There is sometimes an intermediate series of shorter spines between the median radial and adradial, and one between adradial and superomarginal; thus three laterodorsal series, of which the middle (the adradial of young specimens) is more regular and has longer spines; one or two irregular intermarginal series, shorter than marginal spines; inferomarginal spines slightly grooved along one side at tip, or simply flattened and truncate; occasionally not perceptibly flattened but blunter than upper series. Actinal intermediate spines often entirely wanting, even in adult specimens, and when present are arranged in one to four very irregular and often incomplete series which do not extend beyond middle of ray; sometimes only a few irregularly scattered spines are present. Fine creases or lines in the integument proceed outward between the spines, from the adambulacral to marginal plates. Lowest papular areas are the longitudinal intermarginal series, containing upward to twenty-five papulæ to the area.

Preparation of the body wall shows that the papular areas contain many small scattered calcareous grains, most numerous near central portion of each area. In some areas these are arranged in lines and appear to be embryonic plates, while in other areas a few have enlarged sufficiently to form isolated chains of small plates or have even formed an attachment with the nearest trabecula.

Adambulacral plates considerably wider than long, rather small and crowded. Armature consists of (1) a single truncate or round-tipped untapered or tapering furrow spine, 3.5 to 4.25 mm. long, usually flattened and grooved along the upper (or outer) side; (2) on the actinal surface of plate, a similar but generally longer upright spine, usually very conspicuously scoop-shaped at tip. Both spines are covered with membrane, as is also the surface of plates. Some specimens have outer furrow spines longer and slenderer than others or relatively longer than the furrow spines, or more tapered and less conspicuously grooved. The inner or furrow spines vary in the extent and depth of the groove.

Mouth plates with about four marginal spines (rarely five) decreasing in length toward the first adambulacral, the inner or largest being about the same size as a furrow spine and all similarly grooved; one spine on the actinal surface of plate of same size as corresponding adambulacral spines.

Anal opening surrounded by numerous slender papilliform spinelets.

Madreporic body situated at about middle of minor radius, prominent, with more or less sinuous centrifugal striations.

Color in life, general tint cream color, abactinal surface lighter, but apical area buff yellow. In some specimens buffy spots are scattered here and there over surface of body.

Anatomical notes.—Stomach spacious; hepatic or radial cœca large, reaching nearly to end of ray; intestinal cœca large, with numerous small lobes, forming a mass not unlike an ovary in appearance. In the example dissected there are eight or nine of these diverticula lying over the hepatic cœca. Centrally they open into a rather spacious chamber separated from the stomach by a small orifice; dorsally the chamber opens by the anus; the diverticula are about one-third or one-fourth R in length. Retractors of stomach large and strong. One Polian vesicle in each interradius, except that of the madreporic canal; canal slender, sinuous, with easily distinguishable rings of calcareous matter in its walls, reminding one of the trachea of a bird; tube feet with strong sucking disks, and single ampullæ (not two-parted or divided as described by Ludwig in *Alexandraster mirus;* this is a mistake, I think). The ampullæ are rather large and form a double series along either side of the ambulacral ridge, but there is only a single ampulla to each orifice; possibly this double series gave the erroneous impression that the ampullæ are double in *Alexandraster mirus.* Interradial septa membranous, the gonads being attached to the dorsal surface on either side of it, and in the interradial angle. First ambulacral ossicle forked at bottom and heavier than the succeeding ones.

Variations.—This is a variable species in respect to the length, number, and sharpness of the abactinal and lateral spines, those of the type being stouter and less numerous than in others from Monterey Bay and San Diego, California. At the same time there are specimens from the latter locality which are nearly or quite typical and match examples from Monterey Bay. The type has the grooving of the adambulacral and actinal spines more pronounced than in some other specimens from both Monterey Bay and off San Diego. In these the spines are slenderer and the groove instead of running to the base runs only part way down the spine, or is restricted to the tip, and the depth of the groove varies, being very shallow in a few examples. In the type the two adambulacral spines are about equal in length, near the base of ray, the inner shorter distally. More than half of the specimens have the inner considerably shorter all along the furrow; as, for instance, a large specimen from station 4370 has outer spine 5.50 mm. and corresponding furrow spine 4.25 mm. The thickness of the skin is slightly variable, and some examples have the rays more inflated and rigid than others. Certain other variations have been considered in the description and need not be repeated.

Young.—The smallest specimen (station 4361) has R = 8.5 mm., r = 4 mm., and is easy to identify when one is acquainted with the adult. There are three longitudinal rows of abactinal tubercles, in place of spines, and a superomarginal row of tubercles. The inferomarginal plates bear a short stout spine or two. Intermarginal papulæ two to an area; abactinal, one to four. Adambulacral spines prominent, without grooves. Marginal plates prominent, especially the inferomarginals which encroach conspicuously onto the actinal surface; the creature is strongly phanerozoniate. Only one or two actinal interradial spines, and only a few plates. An example from 2893 with R = 12 mm. is much like the above. The characters of the species appear first in a specimen with R = 15 mm. and are pronounced in one with R = 25 mm.

Parasites.—A specimen from 4471 contained a *Dendrogaster*, perhaps of the same species as that figured for *Hippasteria californica*. The starfish has weaker rays and a generally flabbier appearance than two other specimens from the same station. The *Dendrogaster* was found in the body cavity, its branches extending into two rays. The gonads of the starfish are almost rudimentary, although the major radius measures 60 mm.

Type.—No. 309, Stanford University collection (invertebrate series).

Type-locality.—Monterey Bay, near Pacific Grove, California, off shore in about 60 to 70 fathoms, possibly considerably shallower. The type was caught by Chinese fishermen.

Distribution.—Oregon to San Diego, California (and undoubtedly southward), 26 to 159 fathoms, apparently gradually changing in deeper water to the following race.

Specimens examined.—Twenty-seven, from the following stations:

Specimens of Poraniopsis inflata examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2886	Off Heceta Bank, Oregon	50	rocky	1	U. S. Nat. Mus.
2893	Santa Barbara Channel, California	145	fine gray sand, mud	2	Do.
2946	Off Santa Cruz Island, California	150	coarse gray sand	2	Do.
4311	Near San Diego, California	110–143	green mud, fine sand	1	*Albatross*, 1904.
4361	do	97–91	gray sand, mud	1	Do.
4362	do	100–159	fine gray sand	3	Do.
4370	do	99–147	gray sand, rocks	2	Do.
4377	do	127	green mud, sand	1	Do.
4471	Monterey Bay, California	144–65	gray sand, rocks	3	Do.
4535	do	71–54	very hard sand	1	Do.
4551	do	56–46	rocks	1	Do.
4552	do	83–66	green mud, rocks	2	Do.
4553	do	74–65	rocks	1	Do.
4554	do	60–81	green mud	1	Do.
4555	do	66–69	do	2	Do.
4558	do	47–26	rocks	1	Do.
	do			2	Stanford University.

Remarks.—I have examined a large *Poraniopsis* from off Honshu, Japan, 182 fathoms, which differs in a few details from *inflata* and probably represents a different though closely related species. The rays are shorter and the disk larger than in *inflata*, the rays being decidedly broader at the base; R = 2 r. The abactinal spines are numerous, sharp and not arranged in definite rows (except marginals), though on one ray three longitudinal series can be made out between the carinal and superomarginal series (as in extreme examples of *inflata*); no intermarginal spines; adambulacral spines two, round or truncate at tip, flattened and grooved. In proportion to the size of the animal they are longer than in *inflata*. *Inflata* differs, therefore, from the unnamed Japanese species in having a smaller disk, narrower rays, more or less constricted at the base, more regular and usually fewer abactinal spines, intermarginal spines fairly well developed, shorter adambulacral spines, and numerous grains in the integument of papular areas. The two species are close, in fact look more alike than *inflata* and *flexilis*, and may be found to intergrade over the intervening territory, although it is not probable, since all the work in Alaska has failed to bring any specimens to light.

From *P. echinaster* Perrier (equal-sized) specimens of *inflata* differ in having longer narrower rays of a different form (*echinaster* resembles the Japanese species), grooved adambulacral spines, a single (not double) inferomarginal spine to each plate, and longer and more regularly disposed abactinal spines.

Poraniopsis mira (de Loriol)—formerly *Lahillea mira* and *Ortmannia mira*—has the grooved furrow spines of *inflata*, but the abactinal spines have a flattened often capitate top and are quite short and tubercular; and the ventral surface, in addition to the prominent spines, is covered with myriads of minute prickly spinelets. As usual, de Loriol's excellent figures of specific characters render accurate comparison very easy.

PORANIOPSIS INFLATA FLEXILIS Fisher.

Pl. 58, fig. 8; pl. 64; pl. 112, fig. 2.

Poraniopsis inflata flexilis FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 568.

Diagnosis.—Rays longer and slenderer than in *inflata*, very flexible and weak; R = 72 mm., r = 26 mm., R = 2.8 r. Breadth of ray at base, 30 mm. Abactinal surface very weak owing to the slenderer skeletal elements and the larger papular areas which frequently extend from the mid-radial line to the superomarginal plates without a break; meshes of actinal skeleton very wide. Spines slender, long, and sharp; adambulacral spines also slender, tapering, and pointed and without grooves. No calcareous grains and tiny plates in the integument of papular areas.

Description.—The rays are notably slenderer than in *inflata*, especially at the tip; and the integument instead of being rigid is flexible. This is owing to the loose skeleton and the immense papular areas. In the type the adradial line of spines and primary plates is present, but the longitudinal series of intermediate ossicles is wanting so that the two series of dorsolateral papular areas is merged into one. In a specimen from 3104, which if not typical seems to be near this race, there are two dorsolateral rows of papular areas so that this character may not be constant. The spines are weaker than in *inflata* and in seven irregular longitudinal series. On account of the slenderness of the rays distally the actinal intermediate plates do not extend so far along the ray as in *inflata* and the meshes of the skeleton are very large and the trabeculæ slender and weak. Actinal spines few, slender, scattered.

There are only a few intermarginal spines near the base of ray where the intermarginal papular areas are very wide.

Papulæ very numerous to an area. There are no small plates or grains embedded in the integument, as in *inflata*.

The two adambulacral spines are slender and tapering, some pointed, some blunt. The outer is the longer as a rule, although both spines are not at all uniform in length. There is no trace of a groove. Mouth plates with four marginal and one actinal spine, therefore the same as *inflata* except in the form of the spines.

The internal anatomy, madreporic body, and anal papillæ are similar to *inflata*. The ambulacral ossicles are slenderer than in *inflata*. Ampullæ single.

Type.—Cat. No. 27778, U.S.N.M.

Type-locality.—*Albatross* station 4407, off Santa Catalina Island, California, 334–600 fathoms, rocks, shells, fine gray sand.

Distribution.—Central and southern California, in 334 to 600 fathoms; possibly ranging south to the Galapagos Islands and including *Poraniopsis mira* (Ludwig) untenable.

Specimens examined.—Two, the type and a smaller example from 3104, off Half Moon Bay, California (lat. 37° 23′ N.) 391 fathoms, coral; this not quite typical.

Remarks.—The differences which separate this form from *inflata* have been noted above. It seems, from a study and comparison of material, that this is a deep water race of the variable *inflata*. Some specimens of the latter approach *flexilis*. It is very likely that there is a continuous distribution of *inflata* from shallow water into deep water and a consequent change of characters. *Flexilis* seems to be variable also, and the presence of a less strongly differentiated specimen from off central California, north of Monterey Bay, would lend color to the intergradation hypothesis.

Genus HENRICIA Gray.

Linckia FORBES (not Nardo, 1834), Mem. Wernerian Soc., vol. 8, 1839, p. 120.

Henricia GRAY, Ann. and Mag. Nat. Hist., vol 6, 1840, p. 184. Type *H. oculata* Gray=*Asterias sanguinolenta* O. F. Müller.—BELL, Ann. and Mag. Nat. Hist., ser. 6, vol. 6, 1890, p. 472. Since then Bell, Grieg, Scott, Fisher, Clark, and others.

Cribella FORBES (not *Cribrella* Agassiz, 1835), British Starfishes, 1841, p. 100.

Echinaster MÜLLER and TROSCHEL, System der Asteriden, 1842, p. 22 (part). For some reason *Echinaster* has persisted in the writings of Storm 1878, 1879, Stuxberg 1878, 1886, Hoffmann 1882, Jarzynsky 1885, Aurivillius 1886, Brunchorst 1891, Appellöf 1892 (see Ludwig, Fauna Arctica, p. 473).

Cribrella LÜTKEN, Vid. Medd. for 1856, 1857, p. 93; Grönlands Echinodermata, 1857, p. 31. Most authors since then except Gray 1866, Bell 1890, 1892, Grieg 1896, 1898, Scott 1897, Fisher 1906, 1910, Clark 1909.

Diagnosis.—Echinasteridæ with a more or less close meshed skeleton bearing numerous small spinelets either in groups or scattered along the ridges composing the skeleton; marginal plates more or less distinguishable; adambulacral plates with one or more spinelets placed deep within the furrow.

KEY TO NORTH PACIFIC FORMS OF HENRICIA [a]

a^1. One furrow spinelet, except sometimes on the distal portion of ray, where two may be present on the furrow face of the adambulacrals.

b^1. All the pseudopaxillæ or groups of spinelets small, rather close set, the abactinal skeleton not forming an open mesh work; pseudopaxillæ with comparatively few (one to fifteen) short spinelets; papulæ few (one to three, less often four or five) to an area.[b]

c^1. Rays moderately long and slender; marginal plates typically inconspicuous, and not normally forming regular series as in *eschrichtii* (but in some varieties marginal plates are present, when R is considerably greater than 3r and size is frequently larger)........... *sanguinolenta*, p. 271.

c^2. Rays short, stout, and often very tumid; marginal plates with few spinelets, forming regular series.. *eschrichtii*, p. 276.

b^2. Abactinal pseudopaxillæ moderately to very large, close-set, with numerous small delicate, sometimes granuliform spinelets; papular areas small, typically smaller than the pseudopaxillæ; marginal and actinal intermediate plates forming three very regular, conspicuous, usually juxtaposed series.

c^1. Abactinal pseudopaxillæ typically with small granuliform or clavate spinelets; adambulacral spinelets few in about two transverse series. Typically one spinelet in furrow except at very tip of ray where two may be present.

d^1. Papular areas smaller than adjacent pseudopaxillæ which have usually more than twenty spinelets; marginal plates squarish, large, not much wider than long, not separated by prominent transverse grooves (as wide as the elevated ridge of plate); actinal intermediate series reaching quite or nearly to tip of ray............................... *leviuscula*, p. 280.

d^2. Papular areas usually larger than pseudopaxillæ, much sunken, the latter elongated with fewer than twenty spinelets arranged on the tabulate elevation in two or three rows; marginal plates much compressed, the thin spine-bearing tabula separated by fairly deep grooves; actinal intermediate plates not distinguishable much beyond middle of ray.. *annectens*, p. 291.

c^2. Abactinal pseudopaxillæ with numerous slender often glassy spinelets ending in three to several long sharp awns or points; adambulacral spinelets numerous (twenty-five to fifty); typically with two spinelets in furrow beyond middle of ray but only one proximally; actinal intermediate plates extending one-half to three-fourths length of ray.......... *multispina*, p. 286.

b^3. Abactinal skeleton more open, with large often sunken papular areas containing numerous papulæ.

c^1. Spinelets scattered along the ridges surrounding papular areas, often quite small; not in definite clusters or pseudopaxillæ; adambulacral spinelets in a single, sometimes zigzag, transverse series.

d^1. Rays slender, long, and rigid, the skeleton forming an open mesh work with large sunken papular areas; abactinal spinelets minute, generally immersed in the integument and arranged along the trabecular ridges in one to three irregular series; adambulacral spinelets in zigzag transverse series, few, thick, stubby, and immersed in membrane; marginals regular with large intermarginal papular spaces............................ *aspera*, p. 293.

d^2. Rays weak; spinelets comparatively large (as long as the height of ridge bearing them) well spaced, in a single series along the skeletal ridges. Adambulacral spinelets slender, long, in a transverse series, webbed basally, but not impeded by a thick investment. Marginals not always regular.................................... *asthenactis*, p. 297.

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[a] Owing to the variability of the species of this genus identification by a key is unreliable. The accompanying "attempt" will serve to place a specimen near its proper place in the system when recourse must be had to the figures and descriptions. There is a small percentage of specimens that are very difficult to classify even with ample material for comparison; such are usually intergrades, "freaks," or hybrids.

[b] For California specimens which seem to belong here, see also *H. leviuscula dyscrita* and young or dwarfed *leviuscula*.

- c^2. Spinelets in definite pseudopaxillæ or in fascicular groups.
  - d^1. Adambulacral spinelets less than twenty.
    - e^1. General appearance resembling *leviuscula* with small pseudopaxillæ, papular areas not unusually large, often slightly larger than plates; spinelets not in spaced fascicular groups, but in definite pseudopaxillæ; no intermarginals.
      - f^1. General form intermediate between *aspera* and *leviuscula;* papular areas usually small; pseudopaxillæ oblong with two or three rows of upward to twenty very short stubby spinelets; prominent wide and short (compressed) marginals; no intermarginals; adambulacral spinelets short, usually in two transverse series; only one spinelet in furrow all along ray.. *annectens*, p. 291.
      - f^2. General form intermediate between *leviuscula* and *multispina*, but nearer *leviuscula;* abactinal pseudopaxillæ small, often smaller than papular areas, and spinelets numerous, delicate, ending in several minute points; actinal intermediate plates ending near but not at tip of ray; two furrow spinelets near tip of ray; marginal plates not conspicuously compressed, with wide sutures between...... *dyscrita*, p. 289.
    - e^2. General appearance not at all like *leviuscula;* papular areas fairly to very large; spinelets fairly to unusually long, *in spaced fascicular groups;* a long series of intermarginals; marginals not wider than long, armed with a cluster of comparatively long spinelets; adambulacral spinelets unusually long in a zigzag transverse series.
      - f^1. Papular areas not unusually large, about one to two times as wide as the intervening skeletal pieces; actinal interradial areas very small; secondary plates or calcareous grains in papular areas, when present, few...................... *longispina*, p. 299.
      - f^2. Papular areas unusually large, the skeletal pieces slender and forming a wide mesh bearing spaced fascicular groups of spinelets; papular areas containing numerous small calcareous grains, often with a single spinelet; large actinal interradial areas containing numerous plates and papulæ; large intermarginal papular areas..... *aleutica*, p. 300.
  - d^2. Adambulacral spinelets more than twenty; abactinal plates rounded or crescentic (with very numerous, delicate spines) and much less crowded than in *leviuscula;* adambulacral spinelets twenty-five to thirty.................................... *spiculifera*, p. 295.
- a^2. Regularly two or more spinelets on the furrow face of the adambulacral plates all along ray; adambulacral spinelets numerous; rays flexible.
  - b^1. Abactinal and lateral pseudopaxillæ small, evenly spaced; papulæ single, arranged in fairly regular oblique transverse series on either side of the median radial line (at least when viewed internally).. *polyacantha*, p. 302.
  - b^2. Plates small forming a sinuous irregular mesh work inclosing smaller, lower plates also more or less joined in a close mesh between which emerge single papulæ, which do not form transverse oblique rows... *clarki*, p. 303.

Remarks.—A little over one thousand specimens have been examined in preparing the following account of North Pacific species of *Henricia*. Probably no better collection exists, at least for a region of similar extent. Although well acquainted with the variability of starfishes, I have never before met with such an extreme example as the species of this genus present. All attempts at classification are to be regarded as provisional, but in the case of *Henricia* especial emphasis should be directed to this fact. The more diverse individual and other variations become, the more difficult it is to limit precisely the species of a genus, and the more must personal equation and fallible judgment figure in the final decision. For this reason it is probable that another worker, with the same collection would differ considerably in his results. The problem resolves itself into observation and interpretation of not very obvious evidence—evidence in which many important gaps are present and evidence which may be construed in several different ways.

So great and numerous are the variations in most of the species recorded below that each is to be regarded more as a center of variation, deviations from the type proceeding in many directions until they meet and often merge with aberrant members of nearly related forms. This will very likely hold true in many other genera when enough specimens from numerous localities are examined. Another way of stating the idea (which is not new) is this: So-called species of starfishes intergrade in various ways (geographically, bathymetrically, by individual variation, and perhaps also by hybridization) with neighboring and sometimes also with accompanying forms. Many species seem well marked only when we have a few specimens. Furthermore, wide differences in outward structure form no barriers to such intergradation, which may be accomplished from one species to another through a series of intermediate species or races.

With deliberate inconsistency I have called the well-marked types species, disregarding certain indications of intergradation between *sanguinolenta* and *leviuscula*, and between *leviuscula* and *aspera;* and I have called subspecies certain small species which are obviously closely related to and were found to intergrade with *sanguinolenta* and *leviuscula*. Intergradation seems to take place between *sanguinolenta* and *eschrichtii* and *leviuscula;* between *eschrichtii* and *leviuscula;* between *leviuscula* and *multispina;* between *multispina* and *eschrichtii* (not so evident); between *leviuscula* and *annectens*; between *annectens* and *aspera*. Certain of these cases I feel sure are due to hybridism When two or more species range together, "freaks" and aberrant specimens immediately make their appearance. It is sometimes impossible to classify these; they are very baffling. Since hybridism is possible and in some cases probable, it has seemed better to keep such distinct types as *leviuscula* and *aspera* separate from *sanguinolenta*, and to rank under each the races which are evidently most nearly related to them. Thus we have *Henricia leviuscula annectens* and *Henricia leviuscula multispina* rather than *Henricia sanguinolenta annectens* and *Henricia sanguinolenta multispina*, which would obtain if the custom of ornithologists were followed. I am not convinced that the terrestrial subspecies has an exact counterpart in the sea, nor the extreme and baffling variation of the Asteroidea a counterpart in any class of vertebrates.

If the supposed relationships were to be *fully* expressed in the name we should be obliged to denominate the first six species somewhat as follows: (1) *Henricia sanguinolenta;* (2) *Henricia sanguinolenta eschrichtii;* (3) *Henricia sanguinolenta leviuscula* or *Henricia sanguinolenta eschrichtii leviuscula;* (4) *Henricia sanguinolenta leviuscula multispina* or *Henricia sanguinolenta eschrichtii leviuscula multispina:* (5) *Henricia sanguinolenta leviuscula annectens;* (6) *Henricia sanguinolenta leviuscula annectens aspera*. This will indicate why for practical purposes it is better to keep the well-marked types separate, even if evidence of intergradation is present. The subspecies, races, or varieties are in all cases simply deviations from the *type*. *Henricia sanguinolenta annectens* is strictly what should be written, but if the form in question has obviously nothing to do with *sanguinolenta* and is as obviously related to *leviuscula*, I believe the course followed to be the best, even if it is ultimately proved beyond peradventure that *sanguinolenta* and *leviuscula* intergrade without hybridization. Similarly I think it better, if *leviuscula*, *aspera*, and *sanguinolenta* constitute well marked and well differentiated types to keep them separate rather than to subordinate them by a trinomial designation. The study of this collection of *Henricia* has strongly suggested the possibility that all the species of the genus are connected by intergrades, not serially, but by numerous, often anastomosing, lines. The possibilities are somewhat indicated by the puzzling interrelationships of the North Pacific forms.

If the number of species and races recognized seems large, it should be noted that there are probably still more awaiting a name. Three problematical forms were united with *sanguinolenta,* because the evidence of their distinctness was not sufficient or because they seemed scarcely more than extremes of individual variation (possibly mutants or hybrid offspring); several local varieties or variant formæ of *leviuscula* and *multispina* are unnamed; *H. asthenactis* is divisible into slightly differentiated northern and southern races, which seem too insecure to name at present; and *H. clarki* is possibly composed of two very closely related species. It may be added that the course followed was the best according to our lights. The difficulties which each species presented are noted under that species.

Perhaps the sum of this rather lengthened apology for what follows is this: That a system of nomenclature perfected for a rather limited set of animals (the higher vertebrates) may not so well meet the requirements of a different class of creatures which have evolved under very different conditions, and have been subjected to possibly fewer, perhaps more numerous modifying factors. If this system of nomenclature, therefore, is not rigorously adhered to, but is just a trifle altered in order to make it less obviously the awkward instrument that it is, no serious critcism should follow.

Three species of *Henricia* have been described from the region between San Diego, California, and the equator. *H. minuta*[a] (Bell), *H. gracilis*[b] (Ludwig), *H. nana*[c] (Ludwig).

The first is from Ecuador and probably a young specimen; *nana* is from the Galapagos, 53 fathoms, and *gracilis* from off the Tres Marias Islands, Mexico, and from near Chatham, Galapagos, 146 to 680 fathoms. The small size of two of these makes it difficult to compare them with the northern forms, especially as the figures of the entire animal are not sufficiently enlarged to render much assistance. None of them fall under the second division of the appended key, in which two or more spinelets are present on the furrow face of the adambulacral plates. *H. gracilis* resembles in the formation of the skeleton *H. asthenactis,* but its spinulation is of the type of *H. leviuscula dyscrita.* It is apparently distinct (at least subspecifically) from this form. Without specimens for comparison a consideration of the relationships would be of little value, on account of the variability of the species of this genus. *H. nana,* however, seems to be nearest *H. asthenactis* or *H. aspera.* The variety of *H. clarki* recorded from off the Revillagigedo Islands, in the following pages, is entirely distinct from the species described by Ludwig, although I do not feel very certain that the form will not ultimately be found to be a distinct species, when more and larger specimens are obtained.

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[a] Proc. Zool. Soc., 1882, p. 122, pl. 6, fig. 3.

[b] Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 204, pl. 13, figs. 67, 88; pl. 30, fig. 178; pl. 31, fig. 179.

[c] Idem, p. 207, pl. 13, figs. 65, 66; pl. 31, fig. 180.

Henricia spatulifera Verrill (1909*b*, p. 554, fig. 6) from southeast Alaska has not yet been described, so that it is not included in this report. I have not recognized it in the collections, although the figure of the adambulacral and marginal plates is not alone sufficient for purposes of identification. Both *H. leviuscula* and *H. leviusula multispina* may have spatulate adambulacral spinelets.

HENRICIA SANGUINOLENTA (O. F. Müller).

Pl. 65, figs. 1, 2; pl. 66, figs. 1–5; pl. 68, fig. 3.

Asterias sanguinolenta O. F. Müller, Zoologiæ Danicæ Prodromus, 1776, p. 234.

Asterias pertusa O. F. Müller, Zoologiæ Danicæ Prodromus, 1776, p. 235.

Asterias oculata Pennant, Brit. Zool., vol. 4, 1777, p. 52, pl. 30, fig. 56.

Asterias spongiosa Fabricius, Fauna Grœnlandica, 1780, p. 368 (perhaps refers to *eschrichtii* but is practically a *nomen nudum*).

Asterias seposita Retzius, Nya Handl. Kongl. Svenska Vet.-Akad., vol. 4, 1783, p. 237.

Linckia oculata Forbes, Mem. Wernerian Soc., Edinburgh, vol. 8, 1839, p. 120, pl. 3, fig. 5.

Henricia oculata Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 181.

Cribella oculata Forbes, A History of British Starfishes, etc., 1841, pp. 100, 106, fig. p. 100.

Echinaster oculatus Müller and Troschel, System der Asteriden, 1842, p. 24.

Echinaster sanguinolentus M. Sars, Archiv f. Naturg., Jahrg. X, vol. 1, 1844, p. 169; Fauna Litt. Norvegiæ, 1 Heft, 1846, pp. 47–56, pl. 8, fig. 1–37.

Echinaster sarsii Müller and Troschel, Archiv f. Naturg., Jahrg. X, vol. 1, 1844, p. 178.

Linckia pertusa Stimpson, Invert. Grand Manan, 1853, p. 14 (possibly *H. pectinata* (Verrill)).

Cribrella sanguinolenta Lütken, Vid. Medd., 1857, p. 93.—Ludwig, Fauna Arctica, 1900, p. 472 (extensive synonymy and list of localities; includes *eschrichtii* under *sanguinolenta*).

Cribrella oculata P. Fischer, Actes soc. linnéene Bordeaux, vol. 27, 1869, p. 366.—Perrier, Révision des Stellérides, 1875, p. 109.—Sladen, *Challenger* Asteroidea, 1889, pp. 542–543, and numerous other authors.

Cribrella oculata, var. *murina* Perrier, Révision des Stellérides, 1875, p. 112 (Greenland).

Cribrella oculata, var. *cylindrella* Sladen, Trans. Roy. Soc. Edinburgh, vol. 27, 1883, p. 160, pl. 26, fig. 8.

Henricia sanguinolenta Grieg, Bergens Mus. Aarbog, 1894–95, No. 12, 1896, pp. 8, 12.—Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 569.

Note.—The above is not intended to show the complete synonymy of the species, but only the new names and new combinations. For an extensive list of citations consult Ludwig, Arktische Seesterne, Fauna Arctica, vol. 1, 1900, p. 472.

This widely distributed and variable species is represented in the region of Bering Sea by two well-marked forms which it has been deemed advisable to separate under different names. One of these is the common *Henricia* of the Aleutian Islands, the shores of Bering Sea and Arctic Ocean to the east, and of the Kamchatkan-Okhotsk region. It is a short-rayed thick-set form with conspicuous marginals and has been called *Henricia sanguinolenta eschrichtii* (Müller and Troschel). It differs markedly from typical *sanguinolenta* of Norway. The other form is perhaps more variable than the first, and is found usually in deeper water. It has longer, slenderer rays, more numerous adambulacral spinelets, and an inconstant arrangement of the ventral plates in regular series; sometimes there is no sign of regular marginals; sometimes only a series of actinal intermediates is present, all the plates above being irregularly arranged. In an aberrant variety, possibly the result of hybridization, the marginals are large and conspicuous (station 4784).

Diagnosis.—Rays rather slender and long (R = 5 r to 7 r) and size often fairly large; extremely variable, due possibly to crossing with nearly related species (as for example *H. aspera, H. leviuscula*, and *H. leviuscula multispina*). Abactinal pseudopaxillæ small, close-set, with few papilliform spinelets to a group, these groups arranged so as to form a close-meshed network; papular areas thus small with one to three or four papulæ; marginal plates typically indistinct and small, or not distinguishable from the other plates; when distinguishable they are small and two series separated for part of length of ray by a series of small intermarginals; adamulacrals with one spinelet in furrow, and on the surface upwards to fifteen or, in very large examples, even more, spinelets; of these, two or three large ones stand on the furrow margin, forming an angular group and behind them the others very abruptly decrease in length, those on outer part of plate being in a coordinate group. (Typical Scandinavian specimens have fewer spinelets than these.) A single series of actinal intermediate plates, except at base of ray, in large examples, where a second row may be present.

Variations.—The variations are legion and are bewildering. Some of the most baffling varieties (so far as classification is concerned) I believe are due to hybridization of what is here called *sanguinolenta* with *aspera* and *multispina* and perhaps also with *leviuscula*. One who has not been over the numerous specimens in the collection can form no idea of the number of small and large deviations from the type. It has not seemed feasible to name these variations because the specimens are not constant enough to warrant it, and because it is more than probable that some specimens are hybrids. A few of the principal varieties found in the collection are listed below.

Variety A.—Large size, nearly typical as compared with Scandinavian examples; abactinal groups of spinelets small, with few spinelets to a group; marginal plates not distinguishable except at tip of ray; adambulacral spinelets ten, those on furrow margin heavy and slightly compressed at tip (stations 3561, 4803, and others). A slight variation from this form has the spinelets with rather thick skin and the marginal plates forming very inconspicuous and not very regular series among the other plates. They are noticeable by their larger size and more numerous spinelets (station 4281 and others). (Pl. 65, fig. 1.)

Variety B.—Abactinal plates larger (more like small plated *leviuscula*) with twelve to fifteen spinelets; marginal plates easily distinguishable, a long series of intermarginals being present (3214). A freakish looking variety possibly due to hybridization with *multispina;* perhaps only an extreme of the next.

Variety C.—Often very large; abactinal plates variable, either quite small and close set with about twelve to fifteen slender spinelets, and two or three papulæ, or larger with about twenty shorter spinelets. Yet the plates appear small on account of the large size of the specimens. The marginal plates are wide and conspicuous, in regular series, a series of small intermarginals extending far along the ray; a regular series of actinal intermediate plates for about half length of ray, a second for about one-sixth, and sometimes a third on disk; marginal plates with numerous spinelets, and the plates are more or less strongly compressed, so as to be much wider than long, the spine-bearing portion forming a prominent keel; adambulacral plates with upwards to twenty-five or thirty spinelets. A ventral view reminds one strongly of a very large *leviuscula* with compressed marginals, while an abactinal view suggests sometimes *sanguinolenta*, and sometimes *leviuscula* with unusually small plates. (Pl. 65, fig. 2; Pl. 66, figs. 1, 3–5.)

The specimens indicated above have given no end of trouble; in fact, their classification here is tentative. The examples are for the most part large, and two are giants compared with our ideas of *Henricia*. One of these has R = 235 mm., r = 32 mm.; breadth of ray at base 34 mm.; diameter of madreporic body, 6 mm. The other is about the same size. Unless I err, these are much larger than any heretofore recorded *Henricia* (stations 4778, 4784). Two other specimens from 4784 (R = 122 mm. and 116 mm.) are similar to the above in general, but one has the abactinal plates larger, almost large enough to constitute an aberrant *leviuscula*. A suspicious circumstance connected with these aberrant and variable specimens is that with few exceptions they are found along with two or more other species. Of course there is no way to prove that they are hybrids, but the extreme instability of their characters (or infidelity to type) and the intermediate nature of the same strongly suggests such a view. They "act" like hybrids, to use a colloquialism; and, as if the organism were in some way upset, we have giantism. Whatever may be the true explanation of these remarkable variations, it does not seem advisable at present to give them a name.

The characters of this variety are such that they might be produced in different localities by different sets of factors. The specimens from 3602 and 3500 look like simple intermediates between *sanguinolenta* and *leviuscula*, the *leviuscula* appearance dominating on account of the prominent regular ventral rows of plates. Means of discriminating species of *Henricia* are so crude that it is not possible to determine whether all the specimens relegated to this variety really belong there. Some may be simply extreme variations of *leviuscula* and *multispina*.

One is almost forced to conclude that nearly all the so-called species of this genus are simply centers of variability which intergrade (both geographically and bathymetrically) with their associated and neighboring forms.

The following stations at which variety C was taken also yielded other species: 4777, *H. aspera*, *H. leviuscula multispina;* 4778, *multispina;* 4779, the same; 4784, typical *sanguinolenta*, *aspera*, *multispina*, *leviuscula;* 3223, *aspera*, *multispina*, typical *sanguinolenta;* 3602, *aspera*, *multispina*, var.

Variety D.—Six specimens, alike in general features but differing in a few minor details, remain more or less enigmatical. They evidently belong close to *sanguinolenta*, but the abactinal skeleton is much more open than is usual in this species. The spinelets are very small and in spaced clusters of three to six along the top of the ridges which inclose in their meshes incomplete secondary ridges, and about five to eight papulæ. The latter are more or less segregated by the secondary ridges. Actinally the specimens resemble more nearly typical *sanguinolenta* in the adambulacral armature and general appearance of the ventral plates. Two series of marginal plates, an intermarginal series and an actinal intermediate series (all small), are sometimes distinguishable, although the last may be all that is easily seen. It is of course possible that this is a closely related species, but in view of three fairly intermediate examples it has seemed safer to follow the present course. Stations 3331, 3548, 4784, 4792.

Variety E.—This variety intergrades with *eschrichtii* (4779), with variety D, and variety C. It might be considered as a variety of *eschrichtii*, owing to the usually thick rays and small marginal plates. Two specimens from station 3224 are about half way between the prevalent form of variety E and variety D, but are a little nearer the latter abactinally and nearer variety E actinally.

This variety has thick arms and the abactinal skeleton forms a very definite mesh work along which the rather short stubby spinelets are arranged in groups. These groups are slightly spaced and have five to fifteen spinelets in each. The papular areas formed by the meshes are subdivided irregularly by plates which are often more or less isolated and in the minor intervals the papulæ protrude (see pl. 68, fig. 3). Marginal plates are relatively much smaller than in *eschrichtii*, with fewer spinelets. Proximally there are sometimes three rows of actinal intermediate plates, soon becoming one which ends in distal third of ray; proximally sometimes as many as three to five intermarginal series of small, irregularly arranged plates, two series of which persist to the middle of ray, and one sometimes extends to tip, but ordinarily not so far; adambulacral spinelets, five to ten, in one zigzag or two irregular transverse series, similar to typical *eschrichtii*.

Like many other varieties this form at first sight looks like a distinct species, but it intergrades with *eschrichtii*, almost typical specimens of which occur at station 4779. The open character of the skeleton suggests *aspera*, as does also the spinulation of the actinal surface. Again hybridism is probable, for some of the specimens strikingly resemble a mosaic of *sanguinolenta* or *eschrichtii* and *aspera*.

This variety was taken at station 3213 (yielding also *eschrichtii*); 3224 (possibly nearer variety D; *multispina* from this station); 4777 (from this station also *sanguinolenta* variety C, *multispina*, and *aspera*); 4779 (from here an apparent intergrade with *eschrichtii* also, and *sanguinolenta* variety C, *aspera*, *multispina*, and an aberrant *leviuscula*); 4792 (*aspera* and *sanguinolenta* from here).

Type-locality.—Denmark or Norway.

Distribution.—Cape Hatteras to Labrador; Greenland (north to lat. 70° 30′ N.); Iceland and eastward; vicinity of Jan Mayen; Spitzbergen, north to lat. 81° 20′ N.; south along the Scandinavian coast; North Sea, the coasts of Great Britain and Ireland and Faroe Islands; and south to the Bay of Biscay and Azores, to lat. 38° 34′ N. From Finmark eastward and northward to the Murman coast, the White Sea, Barents Sea, Kara Sea, to East Cape; Bering Sea, south to vicinity of Kuril Islands (and northern Japan?), and on the North American coast to Washington. The distribution, therefore, is circumpolar, and south on the continental shores to about lat. 35° to 45° N. The greatest depth at which the species has been taken in the North Pacific is 229 fathoms, but Sladen records a depth as great as 1,350 fathoms. These very deep records must be viewed with some doubt.

Specimens examined.—Seventy-three, from the following stations:

Specimens of Henricia sanguinolenta examined

Station.	Locality.	Depth.	Nature of bottom	Number	Collection
		Fathoms.			
2842	Near Unalaska	56	pebbles	1	U. S. Nat. Mus.
2856	Near Afognak Island, Alaska	68	shells, black specks	1	Do.
2857	do	51	broken shells, gray sand	1	Do.
3214	Near Unimak, Alaska	38	gray sand, gravel	1	Do.
3223	Near Unalaska	56	black pebbles	1	Do.
3480	Amukta Pass, Aleutians	283	black sand, coral, rocks	1	Do.
3225	do	85	black sand	1	Do.
3323	do	51	fine black sand	2	Do.
3561	South of Pribilof Islands	48	gray sand	1	Do.
3597	Admiralty Inlet, Washington	67	coarse black sand	1	Do.
4281	Chignik Bay, Alaskan Peninsula	42	green mud	1	*Albatross*, 1903.
4283	do	30-41	black sand	1	Do.
4293	Shelikof Strait	106-112	blue mud, fine sand	1	Do.
4784	Near Attu Island	135	coarse pebbles	3	*Albatross*, 1906.
4787	Near Medni Island, Commander Islands.	54	green sand	1	Do.
4792	Near Bering Island, Commander Islands.	72	pebbles	3	Do.
4803	Off Simushir, Kuril Islands	229	black sand, coarse pebbles	1	Do.
4804	do	229	do	3	Do.
	Sanborn Harbor, Nagai, Shumagins			1	U. S. Nat. Mus.

VARIETY C.

(Intermediate specimens; some nearer to *H. leviuscula.*)

2846	Near Unimak Island, Aleutians	44	gravel	1	U. S. Nat. Mus.
3213	do	41	black sand	1	Do.
3223	Near Unalaska Island	56	black pebbles	5	Do.
3222	South of Unimak Island	50	black sand	1	Do.
3258	Near Unalaska Island	70	black sand, gravel	1	Do.
3500 [a]	South of Pribilof Islands	121	fine gray sand, gravel	6	Do.
3602 [b]	Southwest of Pribilof Islands	81	green mud	2	Do.
4772	Bowers Bank, Bering Sea	344	green mud, brown sand	3	*Albatross*, 1906.
4777	Near Semisopochnoi Island, Aleutians	52	fine gravel	5	Do.
4778	do	43	fine black gravel	1	Do.
4784 [c]	Near Attu Island	135	coarse pebbles	4	Do.

VARIETY D.

(Found at 4784 (1) and 4792 (1). See list of stations above, and also at the following, where typical *sanguinolenta* was not taken.)

3331	Near Unalaska	350	mud	1	U. S. Nat. Mus.
3548	North of Unalaska	91	black sand	3	Do.

VARIETY F.

3213	Near Unimak Island, Aleutians	41	black sand	1	U. S. Nat. Mus.
4777	Near Semisopochnoi Island, Aleutians	52	fine gravel	1	*Albatross*, 1906.
4778	do	43	fine black gravel	[d] 1	Do.
4779	do	54	broken shells, pebbles, sand.	[e] 7	Do.
4792	Near Bering Island	72	pebbles	1	Do.

[a] Intermediate in general appearance between *sanguinolenta* and *leviuscula*.

[b] Probably extremes of *leviuscula*, or hybrids.

[c] Some specimens nearer *sanguinolenta* abactinally, some nearer *leviuscula*

[d] Near *eschrichtii*.

[e] Stomach full of larval gastropod shells. Two of these specimens close to *eschrichtii*.

Remarks.—The identification of this species, in view of the latitude of variation of which it is capable, is a matter of difficulty and some uncertainty. I am unable to decide just what to make of the several very aberrant forms listed as varieties. If they are really the results of hybridism of course there is nothing gained by naming them. The species seems to be in a very unstable condition, and the extreme variants might, in the opinion of some naturalists, constitute mutations (which is perhaps only another way of saying that hybridization has taken place more or less recently). Whatever the cause of these variations, the fact that they exist is painfully evident to a worker with ample material.

HENRICIA SANGUINOLENTA ESCHRICHTII (Müller and Troschel.)

Pl. 67, figs. 1–3; pl. 68, figs. 1–2.

Echinaster eschrichtii Müller and Troschel, System der Asteriden, 1842, p. 25 (Greenland).—Brandt, in Middendorff's Reise in den äussersten Norden and Osten Sibiriens, vol. 2, Theil 1, 1851, pp. 32, 34 (Okhotsk Sea; var. *microdiscus*, p. 33; var. *macrodiscus*, p. 34).

Cribella eschrichtii Dujardin and Hupé, Hist. nat. zoophytes Echinodermes, 1862, p. 349.

Cribrella sanguinolenta Murdoch, Ray's Report International Polar Exp. to Point Barrow, 1885, p. 159 (Point Franklin).

Cribrella oculata Ludwig, Zool. Jahrb., Abth. f. Syst., vol. 1, 1886, p. 289 (Bering Sea; Metschigmen Bay).

Henricia tumida Verrill, Amer. Nat., vol. 43, Sept., 1909, fig. 5 (p. 555, name only).

Diagnosis.—Rays short and thick, rather tumid, disk large, often greatly arched when animal is brooding eggs. In general appearance this species resembles a short-, thick-rayed *sanguinolenta* abactinally, and actinally a short-, thick-rayed *leviuscula* with small marginal and actinal intermediate plates and few adambulacral spinelets. Abactinal and lateral pseudopaxillæ small close-set with relatively few spinelets, and few papulæ to an area as in *sanguinolenta;* marginal plates in two fairly regular series with few spinelets, the inferomarginal plates the widest; proximally a series of smaller intermarginal plates; a series of small pseudopaxillæ adjacent to adambulacrals; adambulacrals with one furrow spinelet, and on actinal surface five to seven short stubby clavate spinelets in a single zigzag series or occasionally in two, decreasing in size as they recede from furrow.

Description.—Rays five, rarely six. The proportions are rather variable, especially the width of the ray at base. An average specimen from Bering Island: R = 32 mm., r = 12 mm., R = 2.5r; breadth of ray at base 15 mm.; an unusually slender armed example: R = 29 mm., r = 8 mm., R = 3.6r; breadth of ray at base 9 mm.; a remarkably thick-set specimen from Attu is nearly pentagonal; R = 14 mm., r = 10 mm., R = 1.4 mm.; breadth of ray at base, 11–12.5 mm.; height of disk, 11 mm. (Pl. 68, fig. 2.) The disk is nearly always marked by a sulcus or crease in each interradius, and the rays are variously inflated or the disk is greatly arched. These purely "mechanical" differences often lend a deceptive appearance to many specimens. The abactinal surface may be very hard and firm or less often soft; extremity of ray blunt.

The abactinal skeleton is a close mesh work as in *sanguinolenta*, beset with very slightly spaced clusters of short stubby spinelets which average a trifle shorter than in Scandanavian specimens of *sanguinolenta.* Some examples, especially from deeper water, have the spinelets longer and more delicate than the shore forms, and more pointed at the tip; length of spinelets variable. The number of spinelets to each cluster is variable, but few (five to fifteen). Some examples have the general average nearer the larger number, some nearer the smaller. Papulæ one to five to an area, typically one to three. The lateral pseudopaxillæ are generally a trifle smaller than the abactinal.

The marginal plates are clearly defined, forming with the actinal intermediate series three parallel series, the upper of which diverges at base of ray to make room for a short intermarginal series. The actinal intermediate plates do not reach the end of ray. They are small, as a rule about half as wide as the inferomarginals which in turn are wider than the superomarginals. The latter series is often more or less irregular and not well defined. As compared with *leviuscula* these three series have much fewer spinelets and are less conspicuous, being more compressed. The inferomarginals, for instance, are shorter in proportion to width than in *leviuscula*, with about a dozen (frequently fewer) spinelets in two uneven transverse series. There is a series of single intermarginal papulæ and one inframarginal (between the inferomarginals and actinal intermediate plates).

Adambulacral armature sparse, consisting of five to eight stubby spinelets, of which the inner is the largest, arranged in a single zigzag series or more rarely in two on the outer part of the small plate. The furrow spinelet is short, papilliform, and situated deep in furrow. Mouth plates small, with few spinelets.

Madreporic body variable in size, circular, with coarse irregular radiating ridges bearing spinelets.

Color in life probably variable; a specimen from Attu Island, 1906, is labeled "rich creamy white" (Prof. J. O. Snyder); others show a reddish tinge in alcohol, which, however, may be entirely due to the effect of the preservative. Brandt says specimens vary from "Himmelblau bis zum Cyanblau" upper side, and "Zinnoberfarben zum Fleischfarben" beneath.

Variation.—There is variability in the thickness of the arms and their relative length as already noted. The abactinal pseudopaxillæ or clusters of spinelets are also subject to considerable variation. Specimens from Bering Island have the marginals less regular than typical examples, but the latter also occur among the same lot, so the difference is probably purely individual. Examples from the nearer Aleutians occasionally approach *leviuscula* in having larger than typical abactinal pseudopaxillæ, but I have never found any specimens that seemed to prove intergradation. Perfectly typical *eschrichtii* occurs at Kadiak. Examples were taken from a jar containing *leviuscula* possibly showing that the two forms range together.

Care of the young.—This form broods the eggs and takes care of the young for some time after they have metamorphosed. The brood pouch is the region about the mouth, formed by arching the disk and bringing the bases of rays together. Into this cavity the eggs are tightly packed, and are of course protected by the body of the mother. Specimens collected at Agattu, June 8, and at Attu, June 10 and 11, 1906, are with eggs, as also a specimen from Nikolski, Bering Island, June 14. An example collected by the *Corwin* has the brood pouch filled with young about 4 mm. in diameter and with eight pairs of tube feet to a ray. This specimen is figured. (Pl. 68, fig. 1.)

A small variety of *leviuscula* occurring among the rocks at low tide in the vicinity of Monterey, California, and which may be related to *eschrichtii*, also broods its eggs in December and January. (See under *H. leviuscula.*)

Type-locality.—Greenland.

Distribution.—Greenland, and from the Arctic Ocean north of Bering Strait south to Kadiak; westward along the Alaskan Peninsula and Aleutian Islands to Bering Island, Kamchatka, to Sea of Okhotsk (Brandt), and south to Simushir, Kuril Islands. Low tide to 53 fathoms.

Specimens examined.—With one exception all the specimens (253) listed below are from the National Museum collection and that of the U. S. Bureau of Fisheries steamer *Albatross*, 1906. Many of the specimens were collected by Dr. W. H. Dall, between 1871 and 1880, and by others whose names are given in the appended list.

Specimens of Henricia sanguinolenta eschrichtii examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
3213	South of Alaskan Peninsula (Sannak Islands).	41	black sand	5	U. S. Nat. Mus.
3244	Near Hagemeister Island, Alaska	4	fine gray sand	2	Do.
3251	Bristol Bay, Alaska	37	do	1	Do.
3257	Bering Sea, north of Unimak Island	81	gray sand, gravel	1	Do.
3276	North of Alaskan Peninsula (vicinity of Point Moller).	18	gravel, sand, rocks	2	Do.
3278	do	47	fine gray sand	11	Do.
3279	do	41	do	10	Do.
3280	do	36	do	11	Do.
3282	do	53	fine sand, green mud	12	Do.
3285	North of Alaskan Peninsula (vicinity of Cape Kutuzof).	35	gray sand, black specks	3	Do.
3303	do	33	black sand	3	Do.
3497	South of Pribilof Islands	86	gray sand	1	Do.
	Cape Lisburne, Alaska			2	U. S. Nat. Mus., Henry D. Woolfe.
	Bering Strait			1	U S. Nat. Mus., Dr. Robt. White.
	do			2	U. S. Nat. Mus., Lieut. Geo. M. Stoney.
	Port Clarence, Alaska			1	Stanford University.
	Cape Etolin, Nunivak Island, Alaska	8	sand	2	U. S. Nat. Mus., W. H. Dall.
	Hagemeister Island, Alaska			2	Do.
	Hagemeister Strait, Alaska	8–15	gravel	9	Do.
	St. Paul Island, Pribilofs, Alaska	6–9	sand	8	Do.
	Kadiak, Alaska	Shore.		7	U. S. Nat. Mus., *Albatross.*
	Kadiak (Chajafka Cove), Alaska	Shore.		2	U. S. Nat. Mus., W. H. Dall.
	Iliuliuk Harbor, Unalaska	10	shingle	2	Do.
	Popoff Strait, Shumagin Islands, Alaska	Lowest water.		4	Do.
	Sanborn Harbor, Nagai, Shumagins	Lowest water.		25	Do.

Specimens of Henrica sanguinolenta eschrichtii examined—Continued.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
	Sanborn Harbor, Nagai, Shumagins			6	U. S. Nat. Mus., Capt. G. W. Hall
	Round Island, Coal Harbor, Unga, Shumagins.			4	U. S. Nat. Mus., W. H. Dall.
	Unalaska			6	Do.
	Captains Bay, Unalaska			3	Do.
	Captains Harbor, Unalaska	9		1	Do.
	Amaknak, Unalaska			1	Do.
	Port Levashef, Unalaska	20–30		1	Do.
	Nazan Bay, Atka Island, Aleutians			1	Do.
	Adak Island, Aleutians			15	U. S. Nat. Mus., *Albatross*, 1893.
	Constantine Harbor, Amchitka Island, Aleutians.			11	U. S. Nat. Mus., W. H. Dall.
	Kyska Harbor, Kyska Island, Aleutians	Low water.		4	Do.
	....do	9–14	sandy; mud	10	Do.
	Agattu Island, Aleutians	Shore.	rocks	6	*Albatross*, 1906.
	Attu Island, Aleutians	Shore.		9	Do.
	Nikolski, Bering Island, Commander Islands.	Shore.		19	Do.
	Bering Island	Shore.		2	U. S. Nat. Mus., L. Stejneger.
	....do	Shore.		1	U. S. Nat. Mus., N. Grebnitsky.
	Medni Island, Commander Islands	Shore.		8	U. S. Nat. Mus., *Albatross*, 1906.
	Simushir, Kuril Islands (Milne Bay)	Shore.		6	Do.
	Humboldt Bay, Shumagins, Alaska	Shore.	"sand bar"	7	U. S. Nat. Mus., *Albatross*.
	Acc. No. 16889			2	U. S. Nat. Mus., *Corwin*, Capt. M. A. Healy, 1884.
4795.	Near Petropavlovsk, Kamchatka	69–48	green sand, pebbles	1	*Albatross*, 1906.

Remarks.—Müller and Troschel's description of *Echinaster eschrichtii* agrees in the main with this common shore form of Bering Sea. Although there are no records between Point Franklin and Greenland (which is not surprising), I believe I do not err in applying the name *eschrichtii* to the species under consideration. It has seemed desirable to keep this short-rayed, thick-set form with conspicuous marginal plates distinct from typical *sanguinolenta*. Whether it is a distinct species with a distribution nearly coëxtensive with *sanguinolenta* or only a variety of the latter, must for the present remain undecided. I have, however, found several intergrades, and for that reason and the obviously close kinship of *eschrichtii* to *sanguinolenta* have used a trinomial designation.

HENRICIA LEVIUSCULA (Stimpson).

Pl. 69, figs. 1, 2; pl. 70, figs. 1, 2; pl. 71, figs. 2, 3; pl. 111, fig. 6.

Linckia leviuscula Stimpson, Boston Journ. Nat. Hist., vol. 6 (No. 4), 1857, p. 529 (Puget Sound, Washington).

Chætaster californicus Grube, 42 Jahresber. d. schles. Ges. f. vaterländ. Cultur, 1865, p. 52 (possibly refers to *leviuscula*).

Cribrella læviuscula Whiteaves, Canadian Nat., vol. 8, Dec. 20, 1878, p. 466; Trans. Roy. Soc. Canada, vol. 4, sec. 4, 1886 (1887), p. 117.—Sladen, *Challenger* Asteroidea, 1889.—de Loriol, Mem. soc. phys. et d'hist. nat., Genève, vol. 32, pt. 2, No. 9, 1897, p. 14, pl. 2 (17), fig. 2.—Clark, Proc. Boston Soc. Nat. Hist., vol. 29, No. 15, 1901, p. 327.

Cribrella læviuscula crassa Clark, Proc. Boston Soc. Nat. Hist., vol. 29, 1901, p. 327.

Cribrella læviuscula attenuata Clark, Proc. Boston Soc. Nat. Hist, vol. 29, 1901, p. 328.

Henricia leviuscula Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 570.

Diagnosis.—Rays five (rarely six). R = 3 to 7 r; R = upward to 100 mm. General form variable, rays slender, more or less elongated or short and thickened, cylindrical, tapering, blunt; abactinal pseudopaxillæ or groups of spinelets close-set, typically larger than intervening papular spaces; spinelets very short, numerous, and close-set, having as a rule a granuliform appearance under low magnification; adjacent to adambulacral plates three very regular series of juxtaposed plates, the median largest (inferomarginal), but the relative sizes variable; near base of ray the uppermost (superomarginal) series bends upward in the interradial angle, and the triangular area thus formed between the infero- and superomarginals is filled with a variable number of smaller plates. Adambulacral plates wider than long, typically with eight to twelve stubby spinelets in two transverse series, all of these larger than adjacent actinal spinelets and increasing in size toward the furrow, where two are considerably bigger than the rest.

Description.—As the variations in this species are many, a composite description would be unintelligible. For description, what is believed to be the typical form from Puget Sound will be taken. Then some of the principal variations of this type will be noted. R = 89 mm.; r = 13 mm.; R = 6.8 r; R = 49 mm.; r = 11 mm.; R = 4.5 r. Scarcely any two have exactly the same proportions. Breadth of ray at base is slightly greater than r. The abactinal pseudopaxillæ or groups of spinelets are largest on the median radial area of disk and diminish gradually on either side toward the superomarginal plates which are usually abruptly larger. The plates are larger than the intervening papular areas which contain two to five papulæ on the dorsal surface, one or two on the side, and one on the actinal surface. The plates are covered with minute short close-set spinelets, typically 30 to 60 on the larger plates. There are two quite distinct variations even in otherwise nearly similar examples. (1) The spinelets end in a clear, blunt, or more or less pointed, glassy tip, below which are minute denticulations, more or less hidden by the tip, variety A. (2) The spinelets are slenderer, and, as a consequence, less crowded, ending in numerous minute denticulations, there being no sign of the special glassy tip, variety B. In the first variety the dorsal spinulation has a decidedly granuliform appearance, especially as the glassy tips are more globular in some examples. Under a glass the spinelets appear pearly or bead like (when dried). This form of spine may be due to greater age, or to the action of waves. On the ventral surface the glassy tip is sharper and less conspicuous. The dorso-lateral plates are frequently in fairly regular vertical rows, each corresponding to a superomarginal; in the interspace between them are smaller secondary plates. These rows are more regular in the individuals with glassy spinelets, and the presence of the smaller intermediate plates may be another indication of advanced age.

There are three regular rows of conspicuously large, regular plates adjacent to the adambulacrals. The middle row (the inferomarginal) has the largest plates. Usually the upper or superomarginal series has slightly smaller plates, while those of the actinal series, adjacent to the adambulacrals, are smallest. A regular row of mostly single papulæ runs between these series, although that between the actinal and adambulacral series does not extend far along the ray except in old examples. The intra-marginal plates at base of ray do not extend far along ray (about two-thirds of r, measured from interbrachial line).

Adambulacral spinelets variable in number but usually eight to twelve, in the form with glassy spinelets, and twelve to eighteen in the other variety. In the former there are typically two transverse rows, with one or two enlarged furrow spinelets (two in an oblique series, or one median and two in a longitudinal row just back of it). In the variety with slender, multidenticulate spinelets there are usually three transverse rows of spinelets to each adambulacral plate, and two or three furrow spinelets. Intermediate specimens, in respect to the adambulacral armature, are several of the second variety with the armature characteristic of the first. As usual in *Henricia*, there is a curved spinelet on the furrow face of each adambulacral plate. Madreporic body covered with spinelets and with coarse irregular radiating striæ.

Color in life, bright brick red, orange on actinal surface; specimens collected by Dr. J. C. Brown at Port Renfrew, British Columbia, were as above; some small thick-armed examples had slate-gray to lilac or drab disks with the same colors running out upon arms. In other specimens there was a yellowish brown color instead of red as a background, with here and there invasions of brick red on the disk and arms. Specimens from Monterey Bay vary greatly in color, for which see below, "Specimens from Monterey Bay."

Variations.—The littoral form from Puget Sound with very regular marginal plates, eight to fifteen adambulacral spinelets, and the abactinal spinelets ending in numerous sharp denticulations rather than in a solid glassy tip, is assumed to be the typical one. This conclusion is based on an examination of a specimen evidently labeled by Stimpson. The type is therefore one of the various forms of variety B, among those listed herewith.

Variety A.—This form varies in the length and breadth of the rays. The thick-armed examples are usually small, while the medium and slender-armed ones are much in the majority. I take Doctor Clark's *Henricia leviuscula crassa* and *H. l. attenuata* to be variations in proportions of this and the following form, as no differences other than the shape of rays and size of disk are given. Monterey Bay to Kadiak Island. There is less variability in the spinulation of this than of any other variety. (Pl. 69, fig. 1; Pl. 70, figs. 1, 2*a*.)

Variety B.—This is the second variety noted in the foregoing description. The principal differences are in the slenderer and multidenticulate spinelets, more numerous adambulacral spinelets, the absence of any great regularity of dorsolateral plates above the superomarginals (and also the intervening vertical series of spaced smaller plates). Specimens of this variety also vary in respect to proportions from R = 3 r to 7 r. (Pl. 70, figs. 2*b*, 2*c*.)

Specimens occur which are intermediate between variety A and variety B, or which are modifications of A with a slender glassy tip to the granuliform spinelets (station 4205). Such are scarcely separable from variety D.

Variety C.—A fairly typical form, as regards arrangement of plates, has the spinelets stout as in A, but more or less clavate and without a sign of the glassy tip. Adambulacral spinelets 15 to 25, and frequently three on furrow margin (station 4209). From this haul also variety B and a specimen near A.

Variety D.—Some large specimens from offshore are similar to A but have fewer spinelets to the abactinal plates and the glassy tip to the granuliform spinelets is very slender, sharp, and inconspicuous, being sometimes worn off. In these specimens the papular areas sometimes equal or slightly exceed the plates in size and there may be some secondary smaller abactinal plates scattered among the larger. This variety is only a trifle different from the typical form. The marginal plates are regular and abruptly larger than the lateral plates above them (stations 2874, 2886).

Variety E.—A "freak" variety from Monterey Bay (shore) has small abactinal plates with short spinelets of B type, seven or eight adambulacral spinelets which are heavy and spatulate near the furrow, very irregular marginals, the superomarginal series being difficult to follow at middle of ray. (No. 387, Stanford coll., two specimens; station 4431, one specimen.)

Specimens from vicinity of Monterey, California (*Variety F*).—In addition to variety A, which occurs offshore at Pacific Grove, Point Pinos, Monterey, and near Santa Cruz on rocky bottom, the variety B is even more common, and a dwarf form which far outnumbers both of the above. This small variety at first sight, owing to its different coloration, appears to be very distinct from *leviuscula*. I am unable to find constant differences between it and what appear to be really young, or immature, *leviuscula* from Puget Sound and Kadiak. The size of a starfish is not a sure index to its age, which probably partly accounts for the variability of these specimens. The marginal plates, for instance, vary from the proportions of those of *eschrichtii* to those of *leviuscula*.

The abactinal plates are variable in size but of the type of *leviuscula*, the plates being usually larger than the papular areas. Spinelets vary just as in the large specimens, except that the beady or glassy-tipped spinelets are not present. Some specimens have the spinelets conspicuously slenderer, approaching *dyserita* in form. The adambulacral plates are short, with five to eight spinelets in two transverse rows, and a single more or less compressed furrow spinelet much larger than the rest. There are three longitudinal series of regular plates external to the adambulacrals, of which the two outer (marginals) are the largest. The marginal plates are more compressed, less squarish than in large *leviuscula*, and have two to four irregular transverse rows of spinelets pointed outward.

These small *Henricia* are sexually mature at R = 12 mm. A good-sized individual measures about twice that. R equals about 3 r, but the thickness of the ray is variable. They brood their eggs in January, forming for that purpose a concavity about the mouth by arching the disk. The eggs are orange yellow and are hidden by the mother, which in spite of its bright colors, harmonizes fairly well with the coralline on the rocks. However, when brooding the eggs this species is usually found under rocks or hidden between them, in darkness.

So far as I know, no large *leviuscula* has been found brooding eggs, a habit of both *H. sanguinolenta* and *H. eschrichtii*. A knowledge of this would be of great value in determining the status of the form under consideration.

I have specimens of this small variety from Marin County, San Francisco, and Crescent City, California, and from the Straits of Fuca, and Puget Sound. A young *leviuscula* collected along with many large specimens of variety A at Kadiak is not different in any important respects from some Monterey Bay specimens of the dwarf variety, especially as regards the compressed marginals. Dr. J. C. Brown found the dwarf form at Port Renfrew, British Columbia, on the Straits of Fuca, and noted the difference in color, the large examples being uniform brick red above (as at Monterey Bay). I am unable to find any differences between the Monterey and Straits of Fuca specimens except the slightly larger abactinal plates of the latter, these being absolutely typical of *leviuscula* (as in fact are those of some of the Monterey specimens).

I am rather against my will forced to range these small specimens under *H. leviuscula*. In view of the great variability of these specimens and of the lack of any tangible structural difference, it would be hazardous to separate them on the strength of our ignorance of the egg-laying habits of typical *leviuscula*.

The color variations are so decided that the most important are classified below.

1. Variations of brown predominating.

a. Ground color of abactinal surface drab gray mottled with light red, burnt sienna, Van Dyke brown; mottling on disk, or disk and arms; ground color extending over marginals. Actinal surface below marginals yellowish.

b. Ground color dull light brown (tan) variously mottled with brown madder on rays and disk, or disk only; ground color varying to light yellowish brown, and mottling of different intensity.

c. Dull brown, arms tipped with orange (rare).

2. Orange, yellow, or red predominating.

a. Bright orange above with irregular bands of grayish at base of rays; light straw yellow below.

b. Dull vermilion above, yellowish white below.

c. Deep dull yellow (several shades) sparsely mottled with dark reddish brown.

d. Brick red, sparsely mottled with drab.

e. Light reddish (brick) yellow mottled sparsely with brown.

f. Light brown, dull orange, and brown madder of several intensities, marbled together.

3. Lavender and purplish or brown.

a. Ground color lavender, more or less pinkish, mottled on disk and rays, or on rays only with reddish or purplish brown, or more rarely with yellowish brown. Intermediates in ground color between 1 and 3 occur.

4. Various shades of pink or pale lavender (all small specimens).

a. Very pale rose pink, nearly white below.

b. Very pale lavender and lilac.

c. Shades intermediate between these and light yellowish brown.

Type.—An authentic specimen, labeled by Stimpson, in the U. S. National Museum is perhaps the type; if not, it is at least a topotype.

Type-locality.—Puget Sound, Washington.

Distribution.—From Aleutian Islands, Alaska, to Monterey Bay, California, in a typical form, and thence south to the Santa Barbara Channel, and San Diego, California, the southern forms not being typical. The typical form is found along shore at low tide, or in comparatively shallow water. Bathymetrical range, low tide to 53 fathoms.

Specimens examined.—Three hundred and forty-two, from the following stations. (The letters after the number of specimens indicate the varieties as detailed under variations.)

Specimens of Henricia leviuscula examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2864[a]	Straits of Juan de Fuca	48	mud, sand, broken shells	8 B	U. S. Nat. Mus.
2865	Admiralty Inlet, Washington	40	pebbles	1 B	Do.
2874	Off Cape Flattery, Washington	27	rocks and shells	6 D	Do.
2875[a]	do.	40	do.	26 B C D	Do.
2886[a]	Off Oregon	50	rocky	3 B D	Do.
2887	do.	42	coral and pebbles	1	Do.
2913	Cortes Bank off San Diego	26	broken shells	1	Do.
2951	Off Santa Cruz Island	48	fine gray sand	1	Do.
3052	Off Heceta Bank, Oregon	48	coral, broken shells, rocky	2 B	Do.
3053	do.	64	do.	1 B	Do.
3054	do.	53	rocky	1 B	Do.
3087[b]	Off Alseya River, Oregon	46	coral and pebbles	12	Do.
3088	do.	46	do.	3 B	Do.
3444	Straits of Juan de Fuca	80	green mud, pebbles	2 B	Do.
3593[c]	Admiralty Inlet, Washington	37	rocky	1	Do.
3595	do.	49	rocky, gravel, sand	1 B	Do.
4205	do.	26–15	rocks, shells	15 A B	*Albatross*, 1903.
4209	do.	25–24	rocky, coarse sand, shells	3 B	Do.
4431[c]	Off Santa Cruz Island, California	30–41	mud, gray sand	1 E	*Albatross*, 1904.
4779[c]	Near Semisopochnoi, Aleutian Islands.	54	broken shells, pebbles, sand.	1	*Albatross*, 1906.
	Monterey, California	8–12		2	U. S. Nat. Mus., W. H. Dall.
	do.			1 A	U. S. Nat. Mus., H. Hemphill.
	Point Pinos, Monterey Bay, California.	Low tide.	rocks	132 A B E F	Stanford University.
	Capitola, Monterey Bay	Low tide.		1 A	Do.

[a] Some not at all typical.

[b] More or less aberrant variety. Dorsal and marginal plates somewhat smaller than in typical *leviuscula*, and spinelets a trifle more delicate. Some examples with either one or both of the furrow spinelets spatulate and truncate. The specimens are variable.

[c] Aberrant variety.

Specimens of Henricia leviuscula examined—Continued

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
	San Francisco Bay, California			2 B	U. S. Nat. Mus., Dr. John Hornung.
	Marin County, California	Shore.		17 A F	University of California.
	Bolinas, California	Shore.		1 A	Do.
	Crescent City, California	Shore.		1 F	Stanford University.
	Neah Bay, Washington			4 B	U. S. Nat. Mus., J. G. Swan.
	Straits of Juan de Fuca, Washington			5 A B	U. S. Nat. Mus., D. S. Jordan.
	Fort Steilacoom, Puget Sound, Washington.			1 B	U. S. Nat. Mus., Dr Geo. Suckley.
	Puget Sound			4 A B	U. S. Nat. Mus., D. S. Jordan.
	do			5 B	U. S. Nat. Mus., Chas. M. Drake.
	Tacoma, Washington			1 B	U. S. Nat. Mus., Mrs. W. B. Hare.
	Puget Sound			3 A	Stanford University.
	Port Renfrew, Vancouver Island, British Columbia (on Straits of Fuca).	Low tide, rocks.	algæ	9 A B F	Stanford University, John C. Brown.
	Clayoquot Sound, British Columbia	Shore.		1 B	Stanford University, C. H. Gilbert.
	Massett, Queen Charlotte Island, British Columbia.			2 B	U. S. Nat. Mus., J. G. Swan.
	Barclay Sound, British Columbia			8 A B	U. S. Nat. Mus.
	Naha Bay, Alaska	Shore.		1 B	*Albatross*, 1905.
	Sitka, Alaska	15		1 B	U. S. Nat. Mus., W. H. Dall.
	do			3 B	U. S. Nat. Mus., Ferdinand Bischoff.
	Alaska			1 B	U. S. Nat. Mus., Dr. W. H. Jones.
	Fort Wrangel, Alaska			2 B	U. S. Nat. Mus., W. H. Dall.
	Karluk, Kadiak Island, Alaska	Shore.		40 A	Cloudsley Rutter, 1903 (U. S. B. F.).
	Kadiak Island			2	U. S. Nat. Mus.
	Middleton Island, Alaska	10–12	gravel and sand	1 A	U. S. Nat. Mus., W. H. Dall.

Remarks.—This species is the form ordinarily encountered along shore from Monterey Bay to Kadiak, the largest examples coming from the more northern localities. Typical specimens are very easily distinguished by the numerous short almost granuliform appearing spinelets of the large dorsal pseudopaxillæ and by the three regular series of large plates adjacent to the adambulacral series. The adambulacral spinelets are few, short, and robust.

At the south end of Monterey Bay the small variety is the only one at all common. This is found under rocks at low tide usually in more or less sheltered coves where there is a profuse growth of algæ, *Phyllospadix*, and coralline. A few are found on the exposed surface of rocks and on algæ. At Port Renfrew, Vancouver Island, on the Straits of Juan de Fuca, Dr. J. C. Brown, who kindly collected for me, found typical large individuals common at low tide along the rocky shores, where they occurred in pot holes attached to rocks, or kelp, and nearly always submerged. With them were numerous small specimens comparable to the dwarf forms so common at Monterey Bay.

HENRICIA LEVIUSCULA MULTISPINA Fisher.

Pl. 72, figs. 1–4; pl. 73, figs. 1, 2.

Henricia leviuscula multispina Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 571.

Diagnosis.—General form very similar to that of *H. leviuscula* but the abactinal plates more compactly placed, usually smaller and more numerous; the papular areas smaller; the spinelets very numerous, delicate, longer than in *leviuscula* and ending typically in three or four (sometimes more) slender, very sharp points or awns; adambulacral plates with numerous (twenty-five to fifty) spinelets, and typically with two spinelets on the furrow face beyond the middle of ray; proximally only one; actinal intermediate series of plates extending one-half to three-fourths length of ray, not whole length as in *leviuscula.*

Description.—Rays five. R=88 mm.; r=15 mm.; R=5.8 r. Breadth of ray at base, 18 mm. Rays as a rule rather slender, long, gradually tapering. Abactinal plates rather variable in size, but typically smaller and more compactly placed than in *H. leviuscula.* The spine-bearing surface of plate raised and convex as in *leviuscula;* the spinelets are numerous, close-set and bristling, overhanging more or less the papular areas. They are very delicate and glassy when dried, and terminate in three to several sharp awns or points. The spinelets form a very fine close velvety nap all over the surface of the body. It is not possible to count the spinelets with much accuracy, but there are forty to sixty (frequently more) on the median abactinal plates. Dorsally there are two to five papulæ to an area, laterally and actinally three to one.

Superomarginal, inferomarginal, and actinal intermediate plates form three regular series as in *leviuscula* and have also the same relative proportions, but the intermediate series extends only one-half to three-fourths the length of ray. As a rule the superomarginals are abruptly larger than the dorsolateral plates just above. Inferomarginals are conspicuously elongated transversely, usually about twice as wide as the actinal intermediate plates (those adjacent to adambulacrals). The intermarginal plates are variable; sometimes they are confined to a small triangular area at base of ray and sometimes extend halfway along ray as a regular series of small roundish pseudopaxillæ; occasionally a second row is present extending nearly or quite as far as the first. Therefore the superomarginal series is bent upward proximally at the interbrachial angle, while the inferomarginals (as in *leviuscula*) run parallel to the actinal intermediates to the mouth angle. Between these regular series are series of papular areas (except between adambulacrals and actinal intermediate rows where papulæ are present only on disk) with commonly two or three papulæ to an area in large examples. The spinelets of the marginal and actinal plates are similar to those of the abactinal surface, and the plates are compactly placed.

Adambulacral plates with typically twenty-five to forty (sometimes as many as fifty or as few as twenty according to size of specimen) multidenticulate spinelets, those on outer part of plate similar to the actinal intermediate spinelets in size, and increasing in length and thickness toward furrow, on the margin of which are about three or four stout often compressed spinelets. The spinelets are in four to six not very regular transverse series on outer part of plate, and three or four on inner. A characteristic of this form is the presence of two furrow spinelets (one above the other) on the furrow face of the plate, on outer third, half or two-thirds of ray; proximally there is but a single spinelet, as in *H. leviuscula*. In some intermediate or aberrant examples the diplacanthid plates are confined to the tip of ray. No typical examples lack them, however.

Madreporic body slightly convex, circular, of very variable sculpture, but covered with small spinelets similar to those of the adjacent plates.

Color in life.—A specimen from station 4791 was colored in life as follows: Central aboral region pale lilac, fading toward and disappearing near middle of arms; other parts creamy, more yellow toward tips of arms (J. O. Snyder).

Variations.—The typical examples of this species or race (whichever it is) are so different from *leviuscula* that they may be told at a glance. But the deviations from the type are both varied and numerous, so that it is sometimes impossible to decide how a given specimen should be classified. Whatever may be the explanation of the multitude of variations it is certain that the Alaskan specimens present the extreme of difference from *leviuscula*, while the Californian race, *dyscrita*, forms a fairly perfect connecting link. *Dyscrita* has much fewer than the typical number of adambulacral spinelets (usually fifteen or less), fewer and shorter spinelets to the abactinal plates, and two spinelets on the furrow face of the adambulacrals only at tip of ray and sometimes not at all. Certain extremes of *leviuscula* from tide pools of Monterey Bay are so close to extremes of this southern representative of *multispina* that it is well-nigh impossible to separate them. One is forced to conclude that the two forms really intergrade. It is possible that *multispina* is a deeper water variety or race of *leviuscula*, and there is also evidence that the more delicately spined forms are from soft bottom while the short-spined anomalies, so difficult to classify satisfactorily, are the same species or race from hard bottom. However, *multispina* is found along shore, for there are several specimens from Kadiak Island which are nearly like the typical form. From here also are a number of specimens which depart from the type and approach *leviuscula*, and a very few which are intermediate. They were evidently collected along with typical *leviuscula* and presumably occur together (see Kadiak variety below). Still another possibility is that *multispina* is a distinct but variable species which encroaches upon the domain of *leviuscula* (which occurs from low tide to moderate depths) and that whenever this occurs hybridization takes place more or less frequently. In this manner some of the freaks might have originated. The probability of hybridism is very strong in the case of *aspera* and *leviuscula*. When two well-marked forms range together it often happens that specimens are found which are more or less mosaics of these. Such aberrant forms are bewilderingly variable. Some of the more important variations are noted below.

Alaskan specimens.—The specimens which present the extremes of difference from *leviuscula* are from off the Aleutian Islands and Commander Islands. These and other typical examples of the race differ among themselves in the size of the abactinal plates (as shown by the four photographs on plate 72) and in the thickness of the rays, as well as in the extent of the intermarginal plating. The slenderer-armed examples usually have very few intermarginal plates on the rays (only a small triangle in the interbrachial region) while the stouter-rayed specimens have one or two series extending half the length of ray between infero- and superomarginals. The presence of intermarginals is not strictly correlated with thickness of ray, for a specimen with moderately slender rays has the intermarginals well developed (station 4777). Specimens with smaller abactinal plates have finer spinelets.

A well-marked variety occurs at Kadiak Island (Karluk), Herendeen Bay and Port Clarence, Alaska. This has rather thick rays ($R=4$ to $4.5\ r$) more or less swollen at the base, and one or two series of intermarginal plates extending a varying distance along ray. The spinelets are shorter than in typical forms, and the adambulacral spinelets are fewer (about twenty). There are usually two spinelets deep in the furrow, on the outer part of ray. This variety passes into specimens which are difficult to separate from extremes of variety B of *leviuscula*. They may be told usually by the presence of two furrow spinelets near the end of ray and by the actinal intermediate plates not reaching the end of ray. I regard them as intergrades, either by extremes of individual variation or by hybridization. Of course occurring as these intermediates do, all at a single station, the case is different from the intergradation of terrestrial subspecies.

Type.—Cat. No. 27779, U.S.N.M.

Type-locality.—*Albatross* station 4779, near Semisopochnoi Island, Aleutians, 54 fathoms, broken shells, pebbles, sand.

Distribution.—From Oregon to Bering Sea, Bering Strait, the Aleutians, and south to Simushir, Kuril Islands, on the Asiatic side; typical form in moderate depths, a variety more or less intermediate with *leviuscula* occurring at low tide at Kadiak, the Aleutians, and northward. Bathymetrical range to 238 fathoms.

Specimens examined.—One hundred and seven from the following localities:

Specimens of Henricia leviuscula multispina examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2842	Near Unalaska	56	pebbles	1	U. S. Nat. Mus.
2849[a]	Near Shumagin Islands, Alaska	69	green mud	2	Do.
2857	Near Alognak Island, Alaska	51	gray sand, gravel	1	Do.
2862	Off Vancouver Island, British Columbia	238	gray sand and pebbles	1	Do.
2865	Admiralty Inlet, Washington	40	pebbles	2	Do.
2874[a]	Off Cape Flattery, Washington	27	rocks and shells	1	Do.
2877	do	59	black sand and mud	2	Do.
3053	Heceta Bank, Oregon	64	coral, broken shells, rocky	1	Do.
3213	South of Alaskan Peninsula (Sannak Islands).	41	black sand	5	Do.
3223	Near Unalaska	56	black pebbles	4	Do.
3231[a]	Bristol Bay, Alaska	12	stones	6	Do.
3232	do	10	stones, pebbles	14	Do.
3234[a]	do	5	sand, pebbles	6	Do.

[a] These specimens are all more or less intermediate.

Specimens of Henricia leviuscula multispina examined—Continued

Station.	Locality.	Depth	Nature of bottom.	Number	Collection.
		Fathoms.			
3262......	Near Unimak Island, Aleutians......	43	black stones, rocks........	4	U. S. Nat. Mus.
3452......	Straits of Fuca, Washington	125	rocky...	1	Do.
3546......	Near Unalaska......	36	gravel, black sand...	1	Do.
3595......	Admiralty Inlet, Washington......	4[illegible]	rocky, gravel, sand....	1	Do.
3597......	....do......	67	coarse black sand......	2	Do.
4273......	Alitak Bay, Kadiak Island, Alaska ...	3[illegible]-41	green mud, fine sand	1	*Albatross*, [illegible]
4291 [a].....	Shelikof Strait, Alaska	65-48	blue mud, sand, gravel..	2	Do.
4777......	Near Semisopochnoi Island, Aleutians	52	fine gravel...............	1	*Albatross*, [illegible]
4778......	....do..................................	43	fine black gravel....	6	Do.
4779......	....do..................................	54	broken shells, pebbles, sand.	8	Do.
4784.....	Near Attu Island, Aleutians	135	coarse pebbles.....	6	Do.
4791......	Near Bering Island, Commander Islands	76	rocky...	1	Do.
4803......	Off Simushir, Kuril Islands........	229	black sand, coarse pebbles...	1	Do.
	Tacoma, Washington................	....	....	1	U. S. Nat. Mus., Mrs. W. B. Hare
	Unalaska....................	....	....	3	U. S. Nat. Mus., W. H. Dall.
	Sanborn Harbor, Nagal, Shumagin Islands.	lowest water.	....	5	Do.
	West coast North America....	....	....	1	U. S. Nat. Mus. Lieut. Commander H. E. Nichols, U. S. Navy.
	Kyska Harbor, Aleutians [b]........	10	....	1	U. S. Nat. Mus., W. H. Dall
	Semidi Islands (west of Kadiak)........	12-28	gravel.......	1	Do.
	Port Clarence, Alaska [b]...............	....	....	1	Stanford University.
	Bering Island [c]........................	....	....	1	U. S. Nat. Mus.
	Kadiak, Alaska [d]........................	....	....	2	U. S. Nat. Mus., W. J. Fisher.
	St. Paul, Alaska [b]......................	....	....	1	Do.
	Kadiak, Alaska [b]........................	....	....	9	Do.

[a] A probable hybrid between *aspera* and *multispina* in this haul.

[b] Shore specimens are never quite typical, but show a certain resemblance to *H. leviuscula*, with which this form is believed to intergrade.

[c] These as well as a few others may have a slight infusion of *H. sanguinolenta eschrichtii* blood, the two forms range together in places (Port Clarence, Kadiak, Aleutians).

[d] Nearly typical.

HENRICIA LEVIUSCULA DYSCRITA,[a] new subspecies.

Pl. 74, figs. 1-5.

Diagnosis.—Nearly intermediate in general appearance between *H. leviuscula* and *H. leviuscula multispina*, but the abactinal plates smaller with fewer spinelets than in *multispina* and papular areas usually relatively larger; adambulacral plates with about fifteen spinelets (hence fewer than in *multispina*) and with two spinelets in the furrow only at tip of ray, or not at all; spinelets of abactinal plates delicate, similar to those of *multispina*.

Description.—This variable form seems to be a southern variety of *multispina*, intermediate with *leviuscula*. A number of specimens have been classified as intergrades between *dyscrita* and *leviuscula*. Apparently also the transition to typical

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[a] δύσκριτος = hard to determine, referring to the status of the form

multispina is gradual. The specimens may be considered from another point of view as intergrades between *leviuscula* and *multispina*. I think it not improbable, however, that *dyscrita* is an offshore variety or race of southern *leviuscula*, while *multispina* bears a similar relationship to northern *leviuscula*. Certain intergrades between true *multispina* and northern *leviuscula* are therefore difficult to separate from some *dyscrita*. Owing to the extended distribution of the latter, occupying as it does the shallower depths off middle and southern California, it has seemed better to recognize it as a special race rather than as a series of intergrading forms only. The hypothesis as to its derivation would make such a course preferable also.

Rays of moderate thickness to slender; size rather small. R=28 mm.; r=7 mm.; R=4 r. Breadth of ray at base 9 mm. R varies to slightly more or less than 4 r.

Pseudopaxillæ typically smaller than in *leviuscula*, being about as large as intervening papular spaces or even smaller, and not so compactly placed as in *multispina*, in which, even if small, the plates are closely placed, leaving papular areas decidedly smaller than the plates. A comparison of figures will demonstrate this difference. There is less regularity in the shape of the pseudopaxillæ than in typical *multispina*. Spinelets typically like those of *multispina*, rather long, slender, ending in a few sharp points or awns and joined at the base by a slight web (often not present, or not visible). The number of spinelets is quite variable, but usually ranges from fifteen to twenty-five to a plate (less than in *multispina*). Papulæ single, rather large.

There are three regular series of plates external to the adambulacral plates, similar to those of *multispina*. These are less conspicuous than in *leviuscula*, the middle row having the largest plates, and are a little wider, to decidedly wider than long. A short row of small intermarginals at base of ray.

Adambulacrals with one spinelet in the furrow except near tip of ray, where a few plates have two. Adambulacral spinelets ten to fifteen, sometimes a few more or a few less, the two or three largest standing on furrow margin, the others rapidly growing smaller as they recede from furrow. There are two or three transverse rows, and the spinelets themselves are round-tipped with numerous little prickles. The armature is not essentially different from *leviuscula* variety B. The nearer to *leviuscula* the specimen (as indicated by dorsal plates) the fewer the adambulacral spinelets.

Type.—Cat. No. 27780, U.S.N.M.

Type-locality.—*Albatross* station 2907, near Point Conception, California, 44 fathoms, fine gray sand.

Distribution.—Middle and southern California, off shore to about 80 fathoms; south of Monterey Bay this form predominates everywhere over *leviuscula*.

Specimens examined.—Forty-three, from the following localities:

Specimens of Henricia leviuscula dyscrita examined.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms.			
2907	Near Point Conception	44	fine gray sand	1	U. S. Nat. Mus.
2943	Near Santa Barbara Islands	31	rocky	2	Do.
2951	do	48	fine gray sand	2	Do.
2958	do	26	gray sand	1	Do.
2964	do	21	sand, stones	7	Do.
2965	do	27	fine gray sand	4	Do.
2966	do	30	coarse mud	1	Do.
2975[a]	Off Santa Cruz Island	36	gravel, broken shells	1	Do.
3666	Near Monterey Bay	68	mud, sand, bowlders	1	Do.
4420[a]	Between Santa Barbara and San Nicholas Islands.	32–38	fine gray sand	6	*Albatross*, 1904.
4431	Off Santa Cruz Island	30–41	mud, gray sand, rocks	5	Do.
4441[a]	Monterey Bay	35–28	gray sand, black mud	1	Do.
4532[a]	do	30	gray sand	1	Do.
4551	do	56	coarse sand, shells	1	Do.
4554	do	60–80	green mud, rocks	3	Do.
4558[a]	do	40–28	rocks	2	Do.
	Off Wilmington, California	47		1	Do.
	Off San Pedro, California	26–28	green mud, sand	3	Univ. of California.

[a] These specimens are more or less aberrant, being apparently intermediate with *leviuscula*. One from 4420 is aberrant and not at all intermediate. See pl. 74, figs. 3, 4, 5.

HENRICIA LEVIUSCULA ANNECTENS Fisher.

Pl. 70, fig. *2d;* pl. 71, figs. 1, 3.

Henricia leviuscula annectens Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 572.

Diagnosis.—Intermediate in general appearance between *H. leviuscula* and *H. aspera*, but superficially more like *aspera;* rays slender, disk small; abactinal skeleton less open than in *aspera*, with smaller, deeply sunken papular areas; ridges inclosing papular areas not undivided as in *aspera*, but subdivided into spine-bearing tabulæ, or pseudopaxillæ; latter with comparatively few (five to twenty) short tapering stubby spinelets in two or three rows; one to three papular pores to an area; marginal plates shorter and much more compressed than in *leviuscula*, with comparatively few spinelets, the spine-bearing ridges of the two series being sometimes confluent; successive ridges separated by a prominent transverse groove; no intermarginals beyond first two or three marginals; actinal intermediate series extending only part way along ray (one-half to two-thirds) as in *aspera*, not the whole length as in *leviuscula;* adambulacral plates with ten to twelve spinelets in two transverse rows, and deep in the furrow one spinelet, except near tip of ray, where there are two.

Description and variations.—It is doubtful if a detailed description of this form would be of any value. The figures will show the characters sufficiently well. There are numerous variations from the typical form, especially in the size of the abactinal spinelet groups. In some examples the pseudopaxillæ approach the size of those of *leviuscula;* in others they are nearly as inconspicuous as in the southern specimens of *aspera*.

The fact that this variety is intermediate in many of its characters between *leviuscula* and *aspera*, that it is extremely variable, and is found frequently with both *aspera* and *leviuscula*, or *multispina*, naturally suggests that it is a hybrid between the forms mentioned. There is much to support this idea, for the specimens vacillate between the two species, never quite reaching either; nevertheless there are examples which it is difficult to classify, as they might be considered either as aberrant specimens of *aspera* (or sometimes *leviuscula*) or as extreme variants of *annectens*. The "illogical" distribution of the variety makes one somewhat suspicious also.

The chief variation is in the size of the abactinal pseudopaxillæ, as mentioned above, these being narrow and with two rows of spinelets, or more oval with three. The marginal plates are usually abruptly narrower than the abactinal directly above them, the latter being sometimes in irregular transverse lines (as in *leviuscula*) with small secondary plates here and there between the lines. The marginal plates in appearance are about halfway between the thin, sparsely armed *aspera* (with large intermarginal papular areas) and the conspicuous many-spined plates of *leviuscula*. A character of *aspera* is the incomplete actinal intermediate series, which does not run the whole length of ray. The adambulacral plates are nearer *leviuscula* than *aspera*, there being two transverse series of spines, while in *aspera* there is but one. The double-furrow spinelet far along ray is about halfway between the two forms; in *aspera* the double spinelet may occur on most of the plates of the distal two-thirds of ray, or only on a few distal plates; in *leviuscula* it occurs only on a few distal plates, or not at all.

Madreporic body circular, slightly raised, similar to that of *aspera*, traversed by a few radiating ridges bearing spinelets.

Type.—Cat. No. 27781, U.S.N.M.

Type-locality.—*Albatross* station, 3095, off Oregon, 42 fathoms, rocks, stones, shells.

Distribution.—From Washington to Santa Barbara Channel, California, 21 to 73 fathoms.

Specimens examined.—Fifty-seven, as follows:

Specimens of Henricia leviuscula annectens examined.

Station.	Locality.	Depth. *Fathoms.*	Nature of bottom.	Number.	Collection.
2874	Off Cape Flattery, Washington	27	rocks and shells	19	U. S. Nat. Mus.
2875	do	40	do	20	Do.
2877	do	59	black sand, mud	1	Do.
2944	Near Santa Barbara Islands, California	30	rocky	1	Do.
2951	do	48	fine gray sand	2	Do.
2964	Off Santa Barbara, California	21	sand, stones	1	Do.
2965	do	27	do	2	Do.
3095	Off Orford Reef, Oregon	42	rocks, stones, shells	2	Do.
3120	Monterey Bay, California	54	green mud, sand	1	Do.
3595	Admiralty Inlet, Washington	49	rocky, gravel, sand	4	Do.
3597	do	67	coarse black sand	2	Do.
4441	Monterey Bay	35–28	gray sand, black-mud	1	*Albatross*, 1904.
4552	do	73–66	green mud, rocks	1	Do.

Remarks.—This form may be distinguished from *aspera* by the smaller papular areas, the raised groups of spinelets (in *aspera* the spinelets are scattered along the ridges surrounding papular areas and never form pseudopaxillæ), by the coarser spinelets, larger marginal plates, and more numerous adambulacral spinelets, the outer of which are never immersed in membrane; there are two rows of adambulacral spinelets instead of one. From *leviuscula* the present variety is separated by the more open abactinal skeleton, smaller and more spaced pseudopaxillæ, thinner marginal plates, and the incomplete actinal intermediate series. A comparison of photographs will make the distinctions more apparent.

HENRICIA ASPERA Fisher.

Pl. 75, figs. 1–5.

Henricia aspera Fisher, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 127.

Diagnosis.—General form slender (but not invariably so); rays long, disk small; skeleton forming a wide, open meshwork with large papular areas, which are rather deeply sunken between the narrow ridges; abactinally the larger meshes have seven to ten papulæ; spinelets very small, sharp, generally immersed in membranous covering of body and arranged along the summit of the trabecular ridges in one or two irregular series; a regular series of superomarginals, inferomarginals, and actinal intermediate plates (the latter extending half or three-fourths length of ray); a series of intermarginals extending a varying distance in some specimens; also a second series of actinal intermediate plates; adambulacral plates with six to eight coarse spinelets in a single zigzag or a double series, the two nearest furrow margin more or less thickened and considerably larger than the rest; deep in furrow, one or two spinelets.

Description.—Rays five. Type, R = 100 mm.; r = 15 mm.; R = 6.6 r; breadth of ray at base 14 mm. A slenderer rayed form: R = 80 mm.; r = 11 mm.; R = 7.2 r. A large thick-rayed specimen with the arms swollen at base R = 107 mm.; r = 20 mm.; R = 5.3 r; breadth of ray at base, 23 mm. The abactinal skeleton forms an open meshwork, much as in *H. hyadesi* (Perrier), the individual plates being indistinguishable and spinelets very short granuliform, not arranged in evident pseudopaxillæ as in *leviuscula*. Meshes are roundish quadrate, or irregularly polygonal, more open in some examples than in others, containing sometimes one or two small secondary ossicles with a few granuliform spinelets. Meshes usually considerably wider than inclosing trabeculæ, and with five to twelve papulæ on proximal two-thirds of ray, five to seven distally (but fewer in small specimens). Spinelets not crowded but spaced, short, sharp, much shorter and fewer than in *leviuscula*, often reduced to mere granuliform sharp elevations on the plate and more or less obscured by a tight thin skin; arranged along ridges irregularly, but in not over three rows, often in only one irregular series. These rows are interrupted, dividing the spinelets and granules into groups probably corresponding to underlying plates, although no divisions are evident. There are commonly five to fifteen spinelets in one of these groups, but in some specimens they are so obscured by the superficial membranes that only the very tips of the spinelets are visible. They are invisible to the naked eye, and are seen only with a strong glass. Division into groups more evident on sides of ray.

Marginal plates regularly arranged. Superomarginal series departing from interradial angle about midway between dorsal center of disk and inner angle of jaw-plates; occasionally rather irregular near interbrachial angle; plates sometimes transversely elongated, with ten to twelve spinelets. Inferomarginals slightly larger or exactly equal to superomarginals; one or two rows of intermarginal plates on basal fifth of ray; also one or two rows of actinal intermediate plates, two extending about one fifth length of ray, and one series for one half length, beyond which point inferomarginals and adambulacrals are in contact. Intermarginal and inframarginal papulæ; one to six in an area. Marginal plates also form fairly regular transverse series with adambulacrals, although latter are more numerous than former.

Adambulacral plates with one small spine deep in furrow; on some plates, especially in large specimens, a second may be present just above it and in line. On actinal surface two blunt, stubby spines stand in an oblique transverse series on furrow margin (frequently a group of three); and behind them three or four much shorter graduated spinelets in a single zigzag series, all more or less united by membrane. Armature varies greatly, sometimes two transverse series of spines being present, and the spines themselves vary in shape from slender, cylindrical and tapering to thick, clavate, and blunt. Armature generally has appearance of being in a single series and rather sparse. The outer spinelets of some specimens (those which have very minute spinelets generally) are buried in membrane and all but invisible.

Madreporic body variable, usually subtubercular, roundish, with coarse striations.

Color in life.—Abactinal surface deep chrome yellow; papular areas deep saffron yellow; actinal surface pale Indian yellow.

Type.—Cat. No. 21930, U.S.N.M.

Type-locality.—*Albatross* station 3052, Heceta Bank, Oregon, 48 fathoms, on coral and broken shells.

Distribution.—From Bering Sea (Bering Island, Pribilofs, Aleutian Islands) south along the coast to the Santa Barbara Islands, California. Bathymetrical range, 26 to 313 fathoms. On muddy, sandy, pebbly, shelly, and rocky bottom.

Specimens examined.—Seventy-six, as follows:

Specimens of Henricia aspera examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2842	Near Unalaska, Alaska	72	pebbles	2	U. S. Nat. Mus.
2857 [a]	Near Afognak Island, Alaska	68	shells, black specks	2	Do.
2861	Queen Charlotte Sound, British Columbia.	204		2	Do.
2864	Admiralty Inlet, Washington	48	mud, broken shells, sand	2	Do.
2865	do	40	pebbles	2	Do.
2875 [a]	Off Cape Flattery, Washington	40	rocks and shells	3	Do.
2877	do	59	black sand, mud	3	Do.
2887	Heceta Bank, Oregon	42	coral and pebbles	1	Do.
2958 [a]	Near Santa Barbara Islands, California	26	gray sand	2	Do.
2965	Off Santa Barbara	27	fine gray sand	1	Do.

[a] Not typical.

Specimens of Henricia aspera examined—Continued.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms			
2967	Off Santa Barbara	30	coarse mud	1	U. S. Nat. Mus.
3051[a]	Heceta Bank, Oregon	59	coarse broken shells	1	Do
3052	do	48	coral, broken shells	2	Do.
3053	do	64	do	1	Do.
3087	Off Alseya River, Oregon	46	coral, pebbles	6	Do.
3095	Off Orford Reef, Oregon	42	rocks, stones, shells	1	Do.
3119	Monterey Bay, California	54	rocky, coral	1	Do.
3223	Near Unalaska	56	black pebbles	3	Do.
3459	Straits of Fuca, Washington	123	gray sand	1	Do.
3462	Admiralty Inlet, Washington	92	dark sand, rocky	1	Do.
3486	Bering Sea, west of Pribilof Islands	150	green mud, fine sand	1	Do.
3602	do	81	green mud, sand	6	Do.
4239	Junction Clarence Strait and Behm Canal, Alaska.	206–248	coarse sand, rocky	1	*Albatross*, 1903.
4258	Rear Funter Bay, Lynn Canal, Alaska	300–313	mud	1	Do.
4291[a]	Shelikof Strait, Alaska	65–48	blue mud, sand, gravel	1	Do.
4431	Off Santa Cruz Islands, California	30–41	mud, gray sand, rocks	1	*Albatross*, 1904.
4532	Monterey Bay	30	gray sand, rocks	1	Do.
4534	do	86–76	hard gray sand	1	Do.
4535	do	71–54	do	2	Do.
4551	do	56–46	coarse sand, shells, rocks	1	Do.
4552	Monterey Bay (70 Fathom Bank)	73–66	green mud, rocks	3	Do.
4553	do	74–65	rocks	1	Do.
4555	do	66–69	green mud, rocks	2	Do.
4558[a]	Monterey Bay	40–28	rocks	1	Do.
4777	Near Semisopochnoi Island, Aleutians.	52	fine gravel	1	*Albatross*, 1906.
4784[a]	Near Attu Island, Aleutians	135	coarse pebbles	12	Do.
4790	Bering Island, Commander Islands	64	pebbles	1	Do.
4792[a]	do	72	do	1	Do.

[a] Not typical.

Remarks.—This species is easily recognized on account of the rather slender rigid rays, very open and sunken papular areas, the rough minute spinelets, and simple adambulacral armature. It is, however, variable, especially in the southern part of its range, and specimens occur which are difficult to distinguish from *H. leviuscula annectens.* There are indications that this species crosses with *leviuscula*, *multispina*, and *eschrichtii.* It is possible that some of the specimens ranked as *annectens* are hybrids.

In spite of the intermediate nature of many specimens (as for instance *H. leviuscula annectens*) I have kept this well-marked type as a distinct species, for reasons mentioned in the introductory notes to the genus.

HENRICIA SPICULIFERA (Clark).

Cribrella spiculifera CLARK, Proc. Bost. Soc. Nat. Hist., vol. 29, No. 15, May, 1901, p. 328, pl. 2; pl. 3, fig. 1.

Diagnosis.—R = 5 r; rays somewhat tumid near base; abactinal plates rather large and not closely crowded, the plates much less crowded and the groups of papulæ much more numerous than in *H. leviuscula;* plates irregularly rounded or crescentic; marginal and actinal intermediate plates forming three rows all along ray, the latter extending to tip; abactinal spinelets very numerous, longer and slenderer than in *leviuscula;* adambulacral plates with a single spinelet in furrow, and with twenty-five to thirty spinelets on actinal surface, arranged in six or seven series (with three or four to each) parallel to ambulacral furrow.

Description.—The following is the original description:

R : r : : 64 mm.: 14, or 77 mm.: 15. R = 5 r. Breadth of ray near base about 19 mm. Rays somewhat tumid near base, but tapering quite rapidly to a rather attenuate tip; somewhat narrowed at base, and with rather deep interbrachial sulci. Plates of abactinal surface rather large and not closely crowded, the groups of papulæ being much more numerous than in *H. leviuscula* or *sanguinolenta.* The plates are irregularly rounded, or crescentic, with the concave side toward the center of the disk. They are irregularly scattered and show no evidence of arrangement in rows, except along the sides of the rays, where they assume a longitudinal arrangement. Near the tip of the ray, on each side, are three longitudinal rows, the lowest of which consists of small plates lying close to the adambulacral plates and running parallel to that series the whole length of the ray. The two other rows consist of larger plates, and the lower of the two runs the whole length of the ray parallel to the row of small plates. The upper one, however, diverges from the lower about the middle of the ray and runs upward toward the abactinal side of the disk, where it joins the corresponding row of the next ray. The narrow triangular space between this upper row and the lower one is filled by three or four short, irregular rows of somewhat smaller plates. Toward the tip of the ray the plates of the three longitudinal rows are arranged in more or less regular transverse series, but this arrangement is wanting near the base of the ray. Spinelets very numerous on all the abactinal plates, rather longer and more slender than in *leviuscula,* measuring 0.3 mm. in length. The abactinal plates are so much less crowded and the spinelets are so much more numerous and slender than in *leviuscula* that the surface does not appear granular, as it does in that species. Adambulacral plates with a single, stout spine, 0.75 mm. long, high up in the groove, and with twenty-five to thirty spinelets on the actinal surface. These spinelets are arranged in six or seven series parallel to the ambulacral furrow, with three or four spinelets in each series. The spinelets on the edge of the furrow are largest, measuring 2 mm. in length, and each successive series consists of smaller ones, the last series being very small. They are all closely crowded together. Madrepore plate single, small (2 to 3 mm. in diameter), covered with spinelets arranged in ten to twelve rows, radiating from the center. Color of alcoholic specimens uniform dark gray, with a slight yellowish tinge in some lights.

Type.—Probably lost.

Type-locality.—Probably Puget Sound, Washington.

Remarks.—No specimens of *H. spiculifera* have been recognized in the collections which I have examined, so that I can add nothing to the original description. The two types are supposed to be at Columbia University, but are temporarily or permanently lost. If the locality were certain *H. spiculifera* might possibly be considered an extreme variant of the form I have named *multispina.* But in the collection of which *spiculifera* formed a part there were species evidently collected somewhere south of the United States, so that I am not at all convinced that *spiculifera* is really from Puget Sound.

In a general way, *spiculifera* and *multispina* resemble each other. Doctor Clark examined several of the extreme variants of *multispina* and expressed his opinion that none of them represented his species.

The following are the principal differences between *spiculifera* and *multispina*:

spiculifera.	*multispina.*
Abactinal plates not closely crowded, much less so than in *leviuscula.*	Abactinal plates closely crowded, much more so than in *leviuscula.*
Abactinal plates crescentic or irregularly rounded.	Abactinal plates rounded or irregular, not crescentic.
Papular areas subequal to or larger than plates.	Papular areas smaller than plates, and smaller than in typical *leviuscula*, as the plates are more crowded.
Actinal intermediate series of plates extends to tip of ray.	Actinal intermediate series of plates extends only half to three-quarters length of ray.
Adambulacral plates with one spinelet in furrow, and with actinal spinelets (twenty-five to thirty) in six or seven series parallel to furrow.	Adambulacral plates with two spinelets in furrow on outer half to fourth of ray and with actinal spinelets (twenty-five to fifty) not arranged in series parallel to furrow.

The form of spinelet is highly characteristic in *multispina* and probably differs from that of *spiculifera*, although it would not be safe to make comparisons without specimens.

HENRICIA ASTHENACTIS Fisher.

Pl. 77, fig. 1; pl. 111, figs. 4, 4*a*.

Henricia asthenactis FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 572.

Diagnosis.—General appearance somewhat like that of young *aspera*, but the abactinal and lateral skeleton more open and weaker, the papular areas being proportionately much larger and the spinelets scattered, few, and conspicuously longer; adambulacral spinelets long, and in a single transverse series (four to six in number counting the spinelet in furrow); two regular series of plates adjacent to adambulacrals separated by a row of single papulæ.

Description.—Rays, five. Type: R = 22 mm. : r = 5 mm; R = 4.4 r. Breadth of ray at base 6 mm. The rays taper from a broader base than in *aspera* to a sharper point and are more depressed. The skeleton consists of a more open mesh work even than in *aspera*, the ridges being narrow, and surmounted by a single row of slender well-spaced spinelets about as long as the height of the calcareous ridges above level of intervening integument. There appears to be only one or two spinelets to each plate. The large meshes which constitute the papular areas are often squarish, and frequently arranged in fairly regular longitudinal rows, so that three or four rows may be seen when the ray is regarded from above (or six from superomarginal across ray to superomarginal). It so happens that there is also sometimes, but not always, a distinguishable median row of ossicles. The papular areas, especially on disk, may contain one to three small isolated plates bearing one or two spinelets. There are commonly upward of ten papulæ abactinally to each area. While the papular areas are always large, they vary considerably in shape and regularity and are largest on the median area of ray and on disk. It is not possible to appreciate their extent accurately until specimen is dry.

Parallel with the adambulacrals are two series of marginal plates, each of which bears a group or comb of two to four conspicuous spinelets. A short series of actinal intermediate plates is wedged between the inferomarginals and adambulacrals proximally, and similarly a few intermarginal plates, bearing one or two spinelets, occur between the two series of marginals proximally. In some specimens the marginal plates are regular, in others irregular and difficult to follow.

The adambulacral spinelets are typically in a single transverse comb of three to five on the actinal surface, the inner being the longest and much longer than width of plate; the spinelet within the furrow is much shorter and slenderer than the longest of the above—about one-third its length.

Madreporic body small and inconspicuous, with a few coarse striations, and several spinelets on its surface.

Variations.—Two much larger specimens (R=48 mm.) from station 4772, 344 to 372 fathoms, Bowers Bank, Bering Sea, have been referred with some hesitation to this species. As compared with *aspera* the rays are much weaker, the skeletal elements slenderer, the papular areas larger, and not nearly so sunken, the spinelets more delicate, longer, and sharper, and the adambulacral spines longer and slenderer. These specimens differ from those described above in having a series of intermarginal plates nearly to tip of ray, and at the base two or three series. The actinal intermediate series is very variable in length, but does not extend to end of ray. The marginal plates are inconspicuous and bear only two or three spinelets.

Type.—Cat. No. 27782, U.S.N.M.

Type-locality.—Station 4423, between Santa Barbara and San Nicholas Islands, California, 339 to 216 fathoms, green sand shells.

Distribution.—Vicinity of Santa Barbara Island, California; Shumagin Islands, Bering Sea (Bowers Bank and off Kamchatka), 178 to 682 fathoms. The northern form differs more or less from the type.

Specimens examined.—Thirty-eight.

Specimens of Henricia asthenactis examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2948	Off Santa Cruz Island, California	266	gray sand, gravel, broken shells	2	U. S. Nat. Mus.
3338	Off Shumagin Islands, Alaska	625	green mud, sand	1	Do.
4410	Between Santa Catalina and Santa Barbara Islands, California.	178–195	fine gray sand, rocks	7	*Albatross*, 1904.
4416	Between Santa Barbara and San Nicholas Islands, California.	448–323	dark green mud, rocks	1	Do.
4418	do	260–310	black mud, rocks	20	Do.
4421	do	298	gray mud, rocks	1	Do.
4423	do	339–216	green sand, shells	2	Do.
4427	Off Santa Cruz Island, California	475–510	green mud	1	Do.
4772	Bowers Bank, Bering Sea	344–372	greenish brown sand	2	*Albatross*, 1906.
4797	Off Petropavlovsk, Kamchatka	682	green mud, coarse black sand, broken shells.	1	Do.

HENRICIA LONGISPINA Fisher.

Pl. 76, figs. 1, 2; pl. 111, figs. 3, 3*a*.

Henricia longispina FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 572.

Diagnosis.—Rays five, moderately robust, constricted at base, cylindrical, tapering gradually to a very blunt, recurved extremity; disk small, slightly inflated; skeleton forming fairly coarse mesh work with stout plates, and irregular, mostly quadrate or roundish, though often irregular, papular areas, with rather numerous papulæ to an area; spinelets in well-defined, spaced fasciculate groups of two to nine (usually five to seven) and 1 to 1.5 mm. long; extensive intermarginal series of plates; adambulacral armature consisting of a zig-zag series of six or seven long bristling spinelets decreasing in size from furrow edge, and in addition one spinelet deep in furrow; actinal intermediate plates extending only about half length of ray.

Description.—Type, R=47 mm., r=9 mm.; R=5.2 to 4.5 r; rays unequal. Breadth of ray at base, 10 mm.; slightly beyond base, 12 mm. Abactinal and lateral skeleton forms a fairly coarse meshwork with stout plates which at frequent and fairly uniform intervals bear on a slight elevation fasciculate groups of two to nine, usually five to seven, unequal sharp radiating spinelets. The groups are largest usually at the intersection of the skeletal ridges of plates. Between two such nodes there is usually one smaller intermediate fascicule of two or three spinelets. These spinelets, which are skin-covered and thicker in life than when dried, are finely denticulate, sharp, and long for this genus (1 to 1.5 mm.), and much longer and stouter than in any other species. Papular areas irregularly quadrate or roundish, often broken up by a few isolated plates bearing one or two, or less often, more, smaller spinelets than those of the regular plates. As viewed from the outside the papular areas are irregular on account of the smaller secondary plates. Papulæ usually five or six to an area on proximal half of ray, but groups of two or three are sometimes found, and rarely as many as eight or nine. On disk the pseudopaxillæ are closer together and papulæ range from about three to ten to an area. Anus surrounded by several pseudopaxillæ, one probably representing the central plate, having twelve spinelets.

A fairly regular series of pseudopaxillæ extending from interbrachial line, about midway between abactinal and actinal surfaces, reaches tip of arm, and represents the superomarginal plates. About midway between this and edge of furrow is a similar series of inferomarginal plates which are a trifle larger than superomarginals. The plates of both series bear six to nine or ten spinelets, and are somewhat transversely elongated at base of ray. Between supero- and inferomarginal series is a series of small pseudopaxillæ, with one or two to five smaller spinelets, extending one-half to two-thirds length of ray, and at base of ray one or two additional incipient intermarginal series are added to the above. In the small papular spaces between superomarginal and intermarginal series and between latter and inferomarginal are about one to three good-sized papulæ. Just external to adambulacral plates is a series of very small actinal intermediate pseudopaxillæ extending about one-half length of ray, each having two, three, or four spinelets. Between this series and adambulacral plates is a series of single papulæ, and another series between inferomarginal and actinal intermediate plates. After the actinal intermediate plates die out these two series of papulæ merge into a single series (one or two papulæ to an area) between inferomarginals and adambulacrals.

Adambulacral armature consisting of (1) a saber-shaped spinelet situated deep in furrow, unusually prominent, and capped by a short membraneous tip; when bent outward this spinelet reaches about three-fourths across furrow. (2) On actinal surface a rather long slender tapering bluntly pointed spine stands on margin and behind it two similar spines in an oblique transverse series, the inner of these two forming also an oblique series with the marginal spine. Behind these are three or four slightly shorter and sharper spinelets, in a coordinate group, the outermost spinelets the shortest of all. The spinelets stand in a zig-zag transverse series. Occasionally the spinelets form a nearly straight series across the plate. Adambulacral spines larger than any others.

Madreporic body large, situated near edge of disk and covered with numerous spinelets similar to those of pseudopaxillæ.

Color in life, milky white; in alcohol, the same, or yellowish.

Variations.—A smaller specimen from station 4228, vicinity of Naha Bay, southeast Alaska, and consequently from near the type-locality, maintains the general facies of the type, but has only one or two papulæ to each area, few intermarginal pseudopaxillæ, and spinelets which are relatively slightly longer than in type (R=25 mm.).

Type.—Cat. No. 27783, U.S.N.M.

Type-locality.—Station 4199, Queen Charlotte Sound, off Fort Rupert, Vancouver Island, British Columbia, 107 to 68 fathoms, soft green mud, volcanic sand.

Distribution.—From the vicinity of Vancouver Island to southern Alaska.

Specimens examined.—In addition to the type, one specimen from station 4228, vicinity of Naha Bay, Behm Canal, southeast Alaska, 41 to 134 fathoms, gravel, sponges.

Remarks.—This species is notable for the prominent fasciculated spinulation and the prominence of the adambulacral spinelets. The spinelets are much longer and sharper than in *sanguinolenta,* the groups much more spaced on account of the open character of the skeleton, and the adambulacral spinelets much longer.

HENRICIA LONGISPINA ALEUTICA, new subspecies.

Pl. 77, fig. 2.

Diagnosis.—Similar in the character of its armature to *Henricia longispina,* with which it agrees in having the spinelets in spaced fascicules, but from which it differs in having a much more open abactinal skeleton with larger papular areas, in having larger intermarginal papular areas, and extensive actinal intermediate areas with numerous plates and papulæ.

Description.—R = 98 mm.; r = 18 mm.; R = 5.4 r. Breadth of ray at base, 20 mm. The whole skeleton is weaker and more open than in *longispina* and more as in *asthenactis,* but the spinelets instead of being distributed singly along the skeletal pieces (as in *asthenactis*) are in fascicular tufts and much longer than in that species. Meshes of abactinal and lateral surface large, three-, four-, or five-sided, without regularity, and ordinarily about four times the diameter of the skeletal pieces, while in *longispina* they are not more than twice the diameter. The papular areas contain upward to ten minute isolated grains or plates, sometimes bearing a small spinelet. Papulæ conspicuous, three to ten to an area. Spinelets three to five to a fascicule, delicate, pointed and thorny. They are *relatively* smaller than in *longispina*, being 1 to 1.5 mm. long. The tufts of spinelets are situated at the intersection of the skeletal pieces, on slightly raised tabula or bosses, and also one or two may occur on the internodes. The spinelets attached to the grains in the papular spaces are much smaller.

Marginal plates small, the two series well separated by large irregularly quadrate papular areas containing four or five papulæ. Occasionally one of these areas is bisected longitudinally. Intermarginal plates small, extending nearly to end of ray. They are one of the elements of the transverse bars connecting infero- and superomarginal plates. The latter are about the same size as the abactinal pseudopaxillæ, but the inferomarginals are larger, with about eight to ten spinelets.

Actinal intermediate plates small, extending about half length of ray (as in *longispina*), but on the disk and base of ray there are numerous plates, as the inferomarginal series bend outward and reach the ambitus at the interradial angle. Along the interradial line from the mouth to the inferomarginal plate five or six intermediate plates can be counted. These bear one to four short papilliform spinelets. A row of papulæ along ray between inferomarginals and intermediate plates and numerous papulæ among intermediate plates of disk.

Adambulacral plates with an unusually long spinelet in the furrow (2 mm.) and an irregular transverse row of five or six spines, of which the inner is long and slender (twice as long as width of plate), the next two or three decreasing gradually, and the outer one, two, or three are commonly much shorter than the rest. Some of the longer spines are flattened, grooved, or bifid at the tips. The marginal mouth spines are often conspicuously grooved or flattened.

Type.—Cat. No. 27784, U.S.N.M.

Type-locality.—*Albatross* station 4784, near Attu Island, Aleutian Islands, 135 fathoms, coarse pebbles; one specimen.

Remarks.—Although the specimen upon which this race is based is quite different in general appearance from *longispina*, an analysis of its characters shows many points of close similarity. The general type of armature, including that of the adambulacral and mouth plates, is the same. Both species have the long furrow spinelet and the bristling series of adambulacral spines, with certain trivial differences.

The features in which the two forms depart the most widely from one another are in respect to the wide-meshed skeleton of *aleutica* and the larger actinal interradial areas. The abactinal papular areas contain numerous minute plates or grains, some of them bearing small spinelets.

The present form is much more closely related to *longispina* than to any other known species, and in view of the many points of resemblance it has been made a race of that species. More specimens may show *aleutica* to be even nearer *longispina* than the type indicates.

HENRICIA POLYACANTHA Fisher.

Pl. 78, figs. 1, 4; pl. 111, figs. 2, 2*a*–*b*.

Henricia polyacantha Fisher, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 129.

Diagnosis.—Rays moderately slender (R = about 6 r), very flexible, tapering gradually to bluntly pointed, upturned tip; abactinal surface usually more or less collapsed; abactinal and lateral surfaces with small evenly spaced paxillæ; single large papulæ arranged in fairly regular oblique transverse series on either side of median radial line (at least when viewed internally); very small marginal plates; a very regular series of inframarginal papulæ; adambulacral spinelets very numerous, and on the furrow face of plate two to six small saber-shaped spinelets.

Description.—Rays, five. R = 66 mm.; r = 11 mm.; R = 6 r. Breadth of ray at base, 13 mm. Abactinal and lateral surfaces closely covered with small, unequal pseudopaxillæ, leaving, however, papular areas considerably larger than the plates; papulæ, one to an area, large. Without aid of a glass the papular areas appear roundish. Paxillæ more or less elongated in one direction; convex, covered with exceedingly small spinelets, which are numerous, but vary greatly in number, according to the size of pseudopaxilla; ten to forty is the usual number. Paxillæ form a more or less evident median radial line along ray. Frequently two rows of pseudopaxillæ intervene between two papular areas or pores.

External to adambulacral plates is a regular series of actinal intermediate plates, and separated from the latter by a conspicuous regular series of papulæ is a row of smaller inferomarginals. Separating the regular papulæ of this series is a second row of small transversely oriented compressed plates which do not extend the whole length of ray. There is considerable variation in this character; the marginal plates are often quite irregular. Sometimes a superomarginal series can be distinguished just above the inferomarginals, especially on outer part of ray, where the two series are fairly regular. At base of ray the serial arrangement is broken up and two or three additional series of small intermarginal plates are interpolated, a single series of very small ones extending far along ray.

Adambulacral plates separated by a distinct suture. Armature very dense, consisting of many spinelets, as follows: (1) on furrow face of plates two to six small saber-shaped spinelets in a vertical series or group. The number varies in different individuals. Usually there are four to six at base of ray and two or three to each plate beyond middle. Rarely specimens have more than three on plates of distal portion of arm. (2) On actinal surface of plate are thirty to forty slender pointed spinelets arranged in three or four transverse series on inner half of plate, but too crowded on outer half to form rows. Even the inner spinelets are often without regularity. Spinelets decrease rapidly in length and caliber from the furrow outward, the outer spinelets being sharper than the inner and about the same size as those on other actinal plates.

Mouth plates small, triangular, with about four to seven small papilliform spinelets on furrow face. The actinal surface is densely covered with spinelets, of which eight or nine stand on the free margin.

Madreporic body prominent, tubercular, situated midway between center of disk and interbrachial angle, there being small spinelets scattered on the surface. Striations coarse, irregularly radiating.

Color in life unknown; in alcohol whitish.

Anatomical notes.—The plates are rather delicate and slender, as would be expected in a species of this genus living at such a depth. The best idea will be gained from the figure. The papulæ are single, and when viewed from the inner surface of the integument are seen to be arranged in regular oblique transverse series extending between the well-defined median radial series of plates and the superomarginals. Externally the regularity is not very evident.

Type.—Cat. No. 21931, U.S.N.M.

Type-locality.—*Albatross* station 2936, off San Diego, California, in 359 fathoms, on mud.

Distribution.—Known from the vicinity of type-locality only.

Specimens examined.—From type-locality, four; from station 2935, near type-locality, 124 fathoms, fine gray sand, one specimen; locality unknown, one specimen.

Remarks.—This species is characterized by the presence of several spinelets on the furrow face of the adambulacrals and by the small pseudopaxillæ covered with numerous very minute spinelets; by the large single papulæ regularly arranged in oblique transverse rows, and by the small mouth plates and numerous adambulacral spinelets. It stands near to *H. clarki*. and to *H. pauperrima* Fisher of the Hawaiian Islands.

HENRICIA CLARKI Fisher.

Pl. 78, figs. 2, 3; pl. 111, fig. 5; pl. 112, fig. 3.

Henricia clarki Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 573.

Diagnosis.—Rays long, very slender, and flexible, tapering from a narrow base to an attenuate, blunt extremity; rays subcylindrical; abactinal surface depressed; interbrachial angles abrupt, about 90°, not rounded; disk very small; plates delicate, forming a sinuous meshwork inclosing smaller, lower, secondary plates (also more or less joined in a close mesh) between which emerge single papulæ; adambulacral plates with thirty-five to forty spinelets on proximal part of ray, and in the furrow two spinelets, except on the proximal six or eight plates, where there are three to five in a vertical series.

Description.—R=54 mm.; r=7 mm.; R=7.7 r. Breadth of ray at base, 7 to 9 mm. Abactinal surface with an open meshwork of narrow small primary plates, bearing contiguous roundish or elongate groups of about a dozen very small, slender, and sharp spinelets which are not so long as the height of the ridges bearing them. These primary plates form sinuous ridges inclosing fairly large, very irregular spaces or meshes which are filled by lower, smaller plates bearing single spinelets or groups of two to six. These secondary plates in turn form a close meshwork filling the larger primary meshes, but the summit or top of the secondary plates is sunken below the level of the primary ridges and the secondary spinelets are also smaller and fewer in a group. This mesh within a mesh is very characteristic of this species. In the intervals between secondary plates single papulæ protrude.

Toward end of arms primary meshes become smaller and the distinction is not so evident.

On basal third of ray, adjacent to adambulacral plates, is a series of fairly regular plates slightly larger than other plates of general perisome, having twenty to thirty spinelets, but this series soon becomes irregular. One or two tiers of plates above this series there is an indication of a very irregular marginal series, but it does not extend beyond basal fourth of ray. Meshwork on actinal and lateral surfaces much closer than on dorsal, the secondary plates playing a very subsidiary part in the make-up of skeleton. Frequently two or three or even more papulæ occur in the papular spaces.

Adambulacral plates about twice as wide as long, separated by a distinct and conspicuous interval or suture. Armature dense, consisting of (1) two small saber-shaped spinelets placed one above the other high in furrow, except on first six to eight plates, which have a vertical series of three to five. Occasionally on distal portion of ray there is but one furrow spinelet, but two is the usual number. (2) On actinal surface of plate are thirty-five to forty slender pointed spinelets arranged in three or four transverse series on inner half of plates and too crowded to be regular on outer half, decreasing rapidly in length and caliber from the furrow outward, the outer spinelets being sharper than the inner.

Mouth plates forming a salient angle, closing actinostome, the sutures between first adambulacrals and mouth plates marking off a regular pentagon inclosing the ten mouth plates. Of this pentagon the prominent interradial dental sutures mark the radii, while the closed ambulacral furrows form equally regular interradii. Armature very dense, the six or seven marginal spinelets being somewhat enlarged, much flattened, and with blunt or truncate tips; two or three small spinelets form a longitudinal series on furrow face of the plates. The mouth plates are larger and more conspicuous than in *H. polyacantha.* (See Pl. 78, fig. 3.)

Madreporic body prominent, situated midway between center of disk and interbrachial angle, the surface being covered with tufts of small spinelets.

Color in alcohol, whitish.

Anatomical notes.—The appearance of a mesh within a coarser mesh presented by an exterior view of the plates is due partly to the presence of the spinelets which hide the slight gaps between the small secondary plates, although many of the latter are firmly united into a ridge as the figure will show. Undoubtedly the plates are at first independent grains and later coalesce. Comparison of the figures of *H. polyacantha* and *H. clarki* will demonstrate the difference in the skeleton structure. *H. clarki* has no sign of the regular arrangement of the papulæ, characteristic (so far as known) of *polyacantha.* (Compare Pl. 112, fig. 3, with Pl. 111, fig. 2*b*.)

Variations.—The specimens from stations 2923 and 2935 are placed with this species not without serious misgivings. The lack of several specimens from the type-locality by which to determine the range of individual variation has led me to place the specimens in question with *clarki,* although at first sight they look like a very different form. The abactinal spinelets are fewer, and more spaced as regards the small clusters. The meshes are very irregular, but in the example from 2935, which is large (R = 89 mm., r = 12 mm.), the characteristic mesh within a mesh formation is largely obliterated by the growth of the secondary intermediate plates to nearly or quite the coarseness of the primary. This gives a finer-meshed appearance to the abactinal surface. Two young specimens from station 2992 are remarkable in having three or four spinelets in a vertical series on the furrow face of the adambulacrals and fewer adambulacral spinelets, of which those near the furrow are abruptly much larger than the outer ones; the last is true also of the specimens from 2935 and 2923. In these specimens the spinelets near the furrow edge (three to five) are relatively larger than the outer ones, than is the case in the type-specimen. They are thus more like *pauperrima*, but that species has square adambulacral plates and more numerous abactinal spinelets; this species has the spine-bearing surface of the adambulacrals wider than long. The specimens from 2992 (Revillagigedo Islands) are too young to make their identification with this species certain; they are, however, nearer this form than to *pauperrima*, or any described species.

Type.—Cat. No. 27785, U.S.N.M.

Type-locality.—*Albatross* station 4427, off Santa Cruz Island, California, 475 to 510 fathoms, black mud, broken stones; one specimen.

Distribution.—Santa Cruz Island, California, to the Revillagigedo Islands, Mexico, 124 to 822 fathoms.

Specimens examined.—Besides the type, four from the following stations: 2992, Revillagigedo Islands, off Mexico, 460 fathoms, black sand, rocks, two; 2923, off San Diego, California, 822 fathoms, green mud, one; 2935, same locality, 124 fathoms, fine gray sand, one.

Remarks.—*Henricia clarki* differs from *H. polyacantha* (which it resembles in having more than one furrow spinelet and numerous adambulacral spinelets) in the form of the abactinal skeleton, in having the papulæ very irregularly arranged, in having no distinguishable series of marginal plates, in having much larger and more conspicuous mouth plates. The spinelets are longer and sharper. From *H. pauperrima*, of the Hawaiian Islands, to which *clarki* bears considerable outward resemblance, the species differs in having more numerous adambulacral spinelets, and oblong instead of square adambulacral plates. In *pauperrima* there is an indication of the characteristic skeletal structure of *clarki*, but the primary meshes are smaller and do not inclose numerous secondary plates.

This species is named for Mr. Austin Hobart Clark.

Family SOLASTERIDÆ Perrier, 1884, emended.

Spinulosa with a more or less open and irregular reticulate abactinal skeleton (though exceptionally with small roundish or irregular independent plates), the plates bearing paxilliform groups of spinelets; marginals paxilliform, in one or two series; adambulacral spines in a furrow comb and a series at right angles to this; actinal intermediate plates present; with interbrachial septa; no pedicellariæ; no supradorsal membrane; anus present; tube feet in two series with well developed sucking disks.

KEY TO THE KNOWN GENERA OF SOLASTERIDÆ.

a^1. Marginal paxillæ in either one or two series, but if in two then *only* the inferomarginals well developed, the superomarginals being much smaller, and similar to but larger than abactinal paxillæ. Rays more than five.

  b^1. Superomarginal plates, if distinguishable, in a series distinct from inferomarginals; not one or two superomarginals alternating with one inferomarginal in a single linear series.

    c^1. Abactinal plates not independent, but joined by their lobes, or by means of secondary intermediate ossicles.

      d^1. Actinal intermediate plates extending only part way along ray, or confined to disk and not bearing a comb of spines but a paxilliform tuft.................... *Solaster* Forbes, p. 306.

      d^2. A complete series of actinal intermediate plates, each bearing a curved comb of spines, extending to end of ray.. *Rhipidaster* Sladen.

    c^2. Abactinal plates small, unequal, roundish, very numerous and independent. Actinal intermediate plates extending nearly two-thirds length of ray .... *Lætmaster*[a] Fisher.

  b^2. Marginal plates of two kinds in a single linear series—conspicuous transversely oriented, prominently spinous, paxilliform plates alternating with one or two low, longitudinally placed plates with short spinelets; small actinal intermediate plates extending to end of ray; abactinal skeleton wide meshed; paxillæ small; papulæ numerous and large. . *Heterozonias* Fisher, p. 330.

a^2. Marginal paxillæ in two prominent, nearly equally developed series, rays 5. *Lophaster*[b] Verrill, p. 334.

Genus SOLASTER Forbes.

Solaster Forbes, Mem. Wernerian Soc., vol. 8, 1839, p. 120. Type, *Asterias endeca* Linnæus.

Crossaster Müller and Troschel, Monatsber. preuss. Akad. Wiss. Berlin, April, 1840, p. 103; Archiv Naturgesch., 6 Jahrg., vol. 1, 1840, p. 183. Type, *Asterias papposa* Linnæus.

Solaster (subgenus *Endeca*) Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 183. Type, *Solaster endeca.*

Solaster (subgenus *Polyaster*) Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 183. Type, *Solaster papposus.*

Diagnosis.—Solasteridæ with one series of well developed marginal paxillæ, the superomarginals being always markedly smaller than the inferomarginals; abactinal skeleton of eruciform or stellate plates, either closely placed or forming, by means of slender intermediate ossicles, an open meshwork. Abactinal pseudopaxillæ spaced or crowded, small to large, fascicular, tabulate, or penicillate. Actinal intermediate plates extending more or less along ray. Rays seven to fourteen.

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[a] *Lætmaster* Fisher, Smiths. Miscell. Coll. (Quarterly Issue), vol. 52, 1908, p. 88. This is a substitute name for *Ctenaster* Perrier; type, *L. spectabilis* (Perrier). L. Agassiz, in the Mém. soc. sci. nat. Neuchâtel, vol. 1, 1835, p. 192, used *Ctenaster* as a substitute name for *Asterina* Nardo, 1834. Its status corresponds to that of *Cribrella.* This prior use of *Ctenaster* ("Once a synonym, always a synonym") necessitated the renaming of Perrier's genus.

I examined the type in the Museum of Comparative Zoölogy (No. 910). Perrier, in my opinion, has overlooked the chief character by which this form may be separated from *Solaster*, namely, the structure of the abactinal skeleton. The presence of actinal intermediate plates "rather far along the ray" upon which he places primary importance may be duplicated in *Solaster* (in its narrowest sense). But the abactinal plates are very many, small, unequal, delicate, and roundish, with a low column bearing three to six delicate sharp diverging spinelets. They appear to be quite independent, and not forming a meshwork as in other genera of the Solasteridæ. Papulæ extending half way to end of ray.

[b] Including *Sarkaster* Ludwig.

KEY TO THE SPECIES OF SOLASTER HEREIN DESCRIBED.

- a^1. Two rows of marginal plates clearly distinguishable, the superomarginals much the smaller and situated just above the inferomarginals, though sometimes alternating with them. Abactinal skeleton close meshed.
  - b^1. Furrow spinelets much shorter than the actinal adambulacral spinelets, which are not conspicuously long and bristling. Abactinal pseudopaxillæ small, spaced or crowded; marginal plates of both series low and not forming a conspicuous border.
    - c^1. Pseudopaxillæ very small and crowded; disk larger, rays shorter; inferomarginal pseudopaxillæ larger with upward to thirty-two spinelets; superomarginal pseudopaxillæ very small. *endeca*, p. 307.
    - c^2. Pseudopaxillæ larger (but with few spinelets) and more spaced; rays longer, disk smaller. Less difference in size between supero- and inferomarginal paxillæ, the latter with upward to eighteen spinelets (a combination of all these characters necessary rather than a single one without the others, individual variation being wide in both *endeca* and *stimpsoni*). *stimpsoni*, p. 311.
  - b^2. Furrow spinelets long, reaching nearly to tip of actinal spines, which form a bristling fringe all along either side of furrow; pseudopaxillæ more or less tabulate and flat-topped except in *exiguus*, and larger than in b^1. Marginal plates forming a conspicuous border to rays.
    - c^1. Actinal adambulacral comb of spines straight, not curved aborally at inner end; actinal interradial areas small; superomarginals typically opposite inferomarginals.......*dawsoni*, p. 313.
    - c^2. Actinal adambulacral comb of spines curved at inner end; superomarginals typically alternating with inferomarginals.
      - d^1. Disk large, actinal interradial areas large; inferomarginal paxillæ prominent, much broader than long, and somewhat fan-shaped, the spinelets numerous and not longer than the pedicel; furrow spinelets proximally three or four, suboral spines numerous, about fifteen..*paxillatus*, p. 315.
      - d^2. Disk small; actinal interradial areas small, inferomarginal paxillæ subcircular, not fan-shaped, well spaced, with a tuft of delicate spinelets longer than the pedicel; furrow spines proximally two or one, unusually long; suboral spines two to four........*exiguus*, p. 319.
- a^2. Marginal paxillæ of one kind, very conspicuous, well spaced, in a single series (superomarginals practically indistinguishable from abactinal paxillæ).
  - b^1. Abactinal skeleton not wide meshed; paxillæ not large and penicillate, but small with two to seven short spinelets; marginal plates with a few prominent sharp spines; a bare interradial streak along each interradius.
    - c^1. Suboral spines small, one or two, or none; actinal comb of adambulacral spines with two to five, usually four, sharp spines; furrow spinelets small, typically much shorter than the first actinal (less than half); abactinal pseudopaxillæ with three or four short spinelets. *borealis*, p. 320.
    - c^2. Suboral spines five to seven very prominent; actinal comb of adambulacral spines with six long spines; furrow spinelets typically more than half as long as first actinal; abactinal pseudopaxillæ higher, with seven to ten spinelets........................*hypothrissus*, p. 324.
  - b^2. Abactinal skeleton wide meshed; paxillæ large, spaced, and penicillate; marginal paxillæ large with numerous prominent spines.
    - c^1. Furrow spines usually three or four not joined by a web to the actinal comb; marginal paxillæ less numerous, and separated from each other by more than their own width. *papposus*, p. 325.
    - c^2. Furrow spines seven to nine webbed, and joined by a web to the actinal comb; marginals more numerous and separated by less than their own width...............*japonicus*, p. 330.

SOLASTER ENDECA (Linnæus).

Pl. 81; pl. 82, figs. 1, 2, 4.

Asterias endeca Linnæus, Mantissa Plantarum, Appendix, 1771, p. 543.—Retzius, Nya Handl. Kongl. Svenska Vet. Akad., 1783, p. 237.

Asterias aspera O. F. Müller, Zoologiæ Danicæ Prodromus, 1776, p. 234.

Asterias alboverrucosa Brandt, Prodromus, 1835, p. 71 (according to Ludwig).

Stellonia endeca Agassiz, Mém. soc. sci. nat. Neuchâtel, vol. 1, 1835, p. 192.

Solaster endeca Forbes, Mem. Wernerian Soc., vol. 8, pt. 1, 1839, p. 121. Authors since.[a]—Verrill, Amer. Nat., vol. 43, 1909, p. 553 (Bering Sea).

Solaster (Endeca) endeca Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 183.

Solaster galaxides Verrill, Amer. Journ. Sci., vol. 28, July, 1909, p. 59, fig. 2 (Victoria, British Columbia).

Diagnosis.—Rays seven to thirteen, usually nine to eleven; disk broad; rays of moderate length. Distinguished by the numerous small crowded paxillæ with very small spinelets; papulæ usually single; inferomarginal plates low, close together, transversely elongated; superomarginals small, but little larger than adjacent paxillæ; furrow spinelets two or three, exceptionally four, short, not reaching end of actinal spines; latter in a curved series of six to eight, the inner longest, but not of conspicuous length, the longest not exceeding length of base line of comb.

Notes on North Pacific specimens.—Before the publication of Professor Verrill's Descriptions of New Genera and Species of Starfishes from the North Pacific Coast of America,[b] in which *Solaster galaxides* is described, I had set apart the specimens here listed, as *S. endeca*. Professor Verrill kindly identified two examples from station 4246 as his *S. galaxides*. I then went over the whole genus again in the light of other identifications made by Professor Verrill, but have not been able to coincide with his views in regard to the present form. From station 2851, off the Shumagin Islands, Alaska, 35 fathoms, is a fairly large nearly typical *Solaster endeca*. A comparison of this with the so-called *Solaster galaxides* from southern Alaska and other localities has not brought to light any constant differences. Rather has it enforced the conclusion that *galaxides* is not a distinct species, but at most a North Pacific variety of the variable *S. endeca*.

For comparison Atlantic specimens of *S. endeca* from the following localities have been used: off Cape Cod, 33½ to 83½ fathoms (two); Bay of Fundy (one); west coast of Sweden (one). These present considerable variation among themselves, the two examples from off Cape Cod exhibiting almost the maximum of difference. Grieg, in Echinodermen von dem norwegischen Fischereidampfer *Michael Sars* in den Jahren 1900–1903 gesammelt indicates[c] the variability in proportions and in the number of rays of Atlantic specimens, while a good description may be found in Clark's Echinoderms of the Woods Hole Region.[d]

Number of rays, proportions.—Alaskan examples have nine, ten, or eleven rays, usually ten. Atlantic specimens vary in this respect from seven to thirteen, having commonly nine to eleven, and occasionally seven, eight, twelve, and thirteen.

There are not constant differences in proportions between Atlantic and Pacific specimens. For instance, a nine-rayed example from off Cape Cod has $R=3.32\ r$, while the Swedish specimen has $R=2.35\ r$. In the large specimen from off the Shumagin Islands, $R=2.46\ r$, and another from station 4246 has 3.3 r. Another from the same station has $R=2.2\ r$. The types of *S. galaxides* have the ratio $R=2.7\ r$.

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[a] Ludwig in Fauna Arctica, vol. 1, 1900, p. 464, gives a considerable number of references to this species. *S. syrtensis* Verrill, however, is not a synonym of *endeca*.

[b] American Journal of Science, July, 1909.

[c] Bergens Museum Aarbog, 1906, No. 13, p. 66.

[d] Bull. U. S. Fish Comm. for 1902, 1904, p. 556, pl. 3, figs. 13, 14; pl. 4, fig. 23.

Abactinal surface.—Abactinal pseudopaxillæ typically very small and crowded. Specimens from 2851 and 4246 are exactly matched by an example from off Cape Cod. There is less difference between these than between two Cape Cod examples, or between the latter and a Swedish specimen. In large Pacific specimens the spinelets of proximal midradial paxillæ vary from five to about nine or ten. In the Swedish example there are commonly as many as nine, less often ten, and as few as three or four spinelets. The paxillæ on sides of rays are usually very slightly larger than those of the midradial regions and center of disk.

Marginal plates.—In the original description of *S. galaxides:* "The marginal spines are about as in *S. endeca*, but the inferomarginals are more elongated transversely, and bear a decidedly greater number of more minute spinules." The available specimens have been examined with reference to this character. In two equal-sized examples, one from off the Shumagin Islands and one from off Cape Cod, the inferomarginals are the same size, or if anything a little larger in the latter (that is, more elongated transversely). An average plate in the Alaskan example bears thirty-three spinelets, while a corresponding plate in the Atlantic specimen has thirty-one, and in the Swedish example thirty-two; neighboring plates in all three specimens vary three to eight on either side of these figures. Some of the specimens from 4246 have the inferomarginals decidedly *narrower* transversely than any of the above examples; while among all the available material none can be said to have the inferomarginals more elongated transversely. The characteristic is evidently individual and not specific. Again comparing the spinelets for size, we find variation in both Atlantic and Pacific material; the Shumagin Islands example (several times referred to) has *coarser* spinelets than Atlantic specimens. Specimens from 4246 ("*S. galaxides*") have the spinelets variable, some slightly finer, some identical, some slightly coarser than the Cape Cod material. The differences in the inferomarginals of Atlantic and Pacific specimens are no greater than between different individuals from the same locality, or from different localities of the same ocean.

The superomarginals are somewhat more conspicuous than the immediately adjacent abactinal pseudopaxillæ, carrying twelve to fifteen spinelets near the base of ray. They vary in size with the inferomarginals, and as in Atlantic specimens, are sometimes opposite the interspace between two inferomarginals, or else directly above and close to the latter. In shape they are roundish, irregular, or less often subquadrate.

Actinal interradial areas.—In the description of *S. galaxides:* "The synactinal series of pseudopaxillæ extends only to about the basal third of the free part of the ray. They are relatively smaller than in *endeca*, being here only about half size of the inferomarginals proximally. The actinal interradial areas are apparently relatively larger than in *endeca* and bear a larger number of compressed pseudopaxillæ, the larger ones similar to the inferomarginals and synactinals."

The size of the actinal interradial areas depends upon the number of rays and breadth of disk, and while it is possible, by comparing small disked Atlantic *endeca* with larger disked Pacific examples, to find larger interradial areas in the latter, it is also true that a reverse process will reverse the results. As a matter of fact, there is certainly too little difference to be of importance. In the Shumagin Island example the synactinals, instead of being smaller than in Atlantic *endeca*, are distinctly larger, on comparison; but in specimens from 4246 the synactinals are just about the same as in Cape Cod examples. The distance which the actinal intermediate plates extend along the ray is variable in both sets of specimens. In specimens from 4246 the plates extend slightly less to over one-half the length of free part of ray. A comparison of specimens with reference to the above features does not enforce the differences alluded to in the description of *galaxides*.

Adambulacral and dental armature.—Furrow spinelets two or three, rarely four, or near tip of ray only one, and conspicuously shorter than the actinal comb. There is, however, some variation in the length of the furrow spinelets (in both Atlantic and Pacific examples). On the whole, the Pacific examples do not seem to have longer spinelets than the Atlantic, and the limits of variation are about the same in the two lots. When there are two furrow spinelets either one may be the longer, or the two subequal; when three are present usually the median is longest and sometimes one is rudimentary. The actinal comb is curved (not straight as in *dawsoni*) and composed of six to eight sharp skin-covered spinules, the two or three inner the longest and stoutest, the others graded in length toward the outermost. These spines stand little or not at all above the level of the marginal pseudopaxillæ, being therefore different from *dawsoni* and *paxillatus*.

The armature of the mouth plates is typical of *endeca*—seven to nine marginal spinules, of which the inner two or three are much larger than the rest, and six to fifteen suborals, in two series (or a roughly triangular group, the inner spinules being the larger).

Type-locality.—"In Oceano Norvegico" (Linnæus).

Distribution.—Bering Sea south to Victoria, British Columbia (not yet known from the Asiatic coast). In the west Atlantic from Cape Cod to Labrador, thence to Greenland and Davis Strait, Iceland and the Faroe Islands; Ireland, the Irish Sea, Orkneys, Shetland Islands, Scotland, and England (south to lat. 55° N.); northern North Sea to the Kattegat, thence along the Norwegian Coast to Finmark, thence to Spitzbergen and westward to lat. 80° 03′ N., the most northern station yet known; eastward through Barents Sea, along the Murman coast, Kara Sea, thence along the Siberian coast to the Gulf of Khatanga (long. 113° 30′ E.). From here to Bering Sea the species is not yet known. (Emended, from Ludwig, Fauna Arctica, Vol. 1, p. 465.)

Specimens examined.—Twelve, from the following localities:

Specimens of Solaster endeca examined.

Station.	Locality.	Depth. *Fathoms.*	Nature of bottom.	Number.	Collection.
2851	Off Shumagin Islands, Alaska	35	gray sand, broken shells	1	U. S. Nat. Mus.
2862	Queen Charlotte Sound, British Columbia.	238	gray sand and pebbles	1	Do.
4246	Kasaan Bay, Prince of Wales Island, Alaska.	123–101	gray green mud, coarse sand	7	*Albatross*, 1903.
4272	Afognak Island, near Kadiak Island, Alaska.	17–12	sticky mud	2	Do.
	Karluk, Kadiak	Low tide?		1	Stanford University.

Remarks.—If the specimens listed above are true *endeca*, as they seem to be, the known range is thereby considerably increased. The form described by Brandt as *Asterias endeca*, var *decemradiata*, and since called *Solaster endeca decemradiata* probably refers to *Solaster stimpsoni*, but the name is a *nomen nudum* and does not invalidate *stimpsoni*.

SOLASTER STIMPSONI Verrill.[a]

Pl. 82, fig. 3; pl. 83, figs. 1–5.

Asterias endeca, var. *decemradiata* BRANDT (?), Prodromus 1835, p. 71 (*nomen nudum*), Sitka.

Solaster decemradiatus STIMPSON (?), Boston Journ. Nat. Hist., vol. 6, 1857, p. 529.

Solaster Stimpsoni VERRILL, in Appendix C. Report of Progress; Geol. Surv. of Canada for 1878–79, 1880, p. 192 *b*. (Ramsay Id., British Columbia).—J. F. WHITEAVES, Trans. Roy. Soc. Canada, vol. 4, sec. 4, 1886 (1887), p. 116. (Port Neville, British Columbia, Johnstone Strait.)—VERRILL, Amer. Nat., vol. 43, 1909, p. 548.

Crossaster Vancouverensis DE LORIOL, Mém. soc. phys. hist. nat., Genève, vol. 32, pt. 2, No. 9, 1897, p. 12, pl. 1 (16), fig. 5 (Saanich Inlet, Vancouver Island).

Solaster endeca decemradiata CLARK, Proc. Bost. Soc. Nat. Hist., vol. 39, No. 15, 1901, p 325 (Puget Sound).

Diagnosis.—Apparently most nearly related to *S. endeca* but differing in having typically a smaller disk, longer rays, larger and less crowded abactinal paxillæ (which, however, have comparatively few spinelets), and smaller inferomarginal pseudopaxillæ, which have fewer spinelets. Rays ten, occasionally nine. R = 82 mm.; r = 20 mm.; R = 4.1 r. A shorter rayed variety: R = 3.17 r.

Description.—In a typical form this species, or perhaps only subspecies, occurs from Washington to Kadiak. At Kadiak there is some evidence that *stimpsoni* and *endeca* run together, for it is difficult to assign certain specimens to their proper species. As the two forms range together here they may possibly hybridize.

The photographic figures will reveal the tangible differences nearly as well as a detailed description. The description will be in the nature of a comparison of *stimpsoni* with *endeca.*

Typically the rays are longer and somewhat slenderer than in Pacific *endeca.* The pseudopaxillæ are perhaps two or three times as large, having coarser and blunter spinelets, six to twelve to a group on the proximal radial regions. These spinelets are sometimes sheathed to their tips in a continuous web and sometimes radiate apart forming a floriform group of six to ten peripheral and one or two central spinelets. These paxillæ are not always relatively more widely spaced than in *endeca*, but on account of their smaller number and larger size appear to be. In certain extreme variants—those from the southern part of the range—the paxillæ are actually more widely spaced. The most obvious difference however is in the size of the paxillæ and component spinelets.

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[a] Verrill (1909*a*, p. 60, figs. 3 and 4) has described *Solaster constellatus*, "an eight-rayed species with small disk and long, tapered arms." R=3.7r. It resembles *S. stimpsoni*, but the pseudopaxillæ are larger, though with only four or five to eight spinelets. The inferomarginals are small, with eight to twelve spinelets, while the superomarginals are subequal to the abactinals. The adambulacral spines consist of a furrow series, with two or sometimes three rather short, tapered spines and an outer comb of six or seven nearly equal tapered spines, webbed nearly to the tips; the inner ones are usually rather longer, so that the rows are a little graded. Professor Verrill kindly sent me abactinal and actinal photographic views of this form. In view of the variation in the abactinal paxillæ of *S. stimpsoni*, and the great similarity, almost identity in marginal and adambulacral armature of *stimpsoni* and *constellatus*, the main distinction remaining is the difference in the number of rays. I am strongly inclined to regard *S. constellatus* an eight-rayed variety of *stimpsoni*. *S. paxillatus* has an eight-rayed form.

The inferomarginal pseudopaxillæ are not so wide as in *endeca* and bear fewer (twelve to eighteen) coarser spinelets. The plates are only slightly wider than long. Superomarginals slightly larger than adjacent abactinal paxillæ and about one-third to one-half as large as the adjacent inferomarginals. There is variation in the size of the superomarginals. They are about as large as the midradial paxillæ.

Actinal interradial areas typically smaller than in *endeca*, and containing fewer paxillæ similar to those of abactinal surface, but with fewer (four to seven) spinelets. A single series of paxillæ extends a very short distance along free part of ray (perhaps one-fifth to one-fourth length).

Furrow spinelets two or three (only one near the end of ray), short, of the type of *S. endeca.* Actinal comb curved aborad at inner end, and containing six to eight blunt rough-tipped spinules decreasing in length from the furrow. These combs extend little if any above the level of the marginal plates to which they are adjacent throughout most of the ray. The adambulacral armature does not present any very striking differences. One difference, however, is apparent though perhaps not constant. In *endeca* the actinal comb is slightly curved throughout its whole length, but in *stimpsoni* it is straight on the outer part and abruptly curved at the inner end. In this feature *stimpsoni* is intermediate between *endeca* and *dawsoni.*

Mouth plates similar to those of *endeca;* marginal spinelets six to eight, the inner two or three enlarged as in *endeca* but in extreme specimens shorter and stouter. Suborals four to eight, in a single series (usually double in *endeca*) shorter and stouter as a rule than in *endeca*, but not invariably so.

Color in life: A specimen from Friday Harbor, Washington, has the center of disk and a broad band proceeding thence along the middorsal region of each ray leaden blue, shading to yellow ochre on interradii and rest of rays, except inner half of each subambulacral comb, and mouth plates, which are like dorsum, bluish.

Cotype.—In the Yale University Museum.

Type-locality.—Ramsay Island, British Columbia.

Distribution.—Southern Bering Sea (Commander Islands), and Kadiak, south to Oregon, in shallow water.

Specimens examined.—Twenty-one, from the following localities:

Specimens of Solaster stimpsoni examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2874	Off Cape Flattery, Washington	27	rocks and shells	1	U. S. Nat. Mus.
3096	Off Orford Reef, Oregon	33	rocks, broken shells	1	Do.
	Kadiak, Alaska			9	U. S. Nat. Mus., W. J. Fisher.
	Bering Island, Commander Islands.			3	U. S. Nat. Mus., L. Stejneger.
	Belkoffski, Alaska			1	U. S. Nat. Mus., W. H. Dall.
4205	Admiralty Inlet, vicinity of Port Townsend, Washington.	26-15	rocks, shells	1	*Albatross*, 1903.
4209	do	25	rocky, coarse sand, shells	1	Do.
	Karluk, Kadiak, Alaska	Low tide.		2	Stanford collection.
	Port Renfrew, Vancouver Island, British Columbia.	Low tide.		1	Stanford collection, J. C. Brown.
	Friday Harbor, San Juan Islands, Washington.	Low tide.		1	Stanford collection, F. W. Weymouth.

Remarks.—As the foregoing description is largely a comparison of *stimpsoni* and *endeca* it will not be necessary to state again the differences which separate the two forms. It is not possible to determine satisfactorily the relationship of the two species. Although the extremes are certainly very distinct, at Kadiak Island they either hybridize or approach each other more closely than elsewhere, judging by nine dried specimens in the collection. The Bering Island specimens are not typical *stimpsoni* as the rays are too short and the marginal plates larger than in typical specimens. The abactinal paxillæ resemble those of *stimpsoni*. These specimens may really be only a variety of *endeca* with unusually large paxillæ.

SOLASTER DAWSONI Verrill.

Pl. 84, figs. 1, 2; pl. 85, figs. 1, 2; pl. 86, figs. 1, 2; pl. 113, fig. 1.

Solaster dawsoni VERRILL, in Appendix C, Report of Progress, Geol. Surv. of Canada for 1878–79, 1880, p. 193 *b*.—J. F. WHITEAVES, Trans. Roy. Soc. Canada, vol. 4, sec. 4, 1886 (1887), p. 116 (Powell Island, Straits of Georgia, Melaspina Inlet, Johnstone Strait, Goletas Channel).

Solaster endeca MURDOCH, Report of the International Polar Expedition to Point Barrow, Alaska, 1885, p. 159.

Diagnosis.—Rays eight to thirteen (commonly eleven or twelve) stout; disk moderately large. A large specimen: R = 163 mm.; r = 48 mm.; R = 3.4 r. R varies to 2.5 r. Differing from *S. endeca* in having larger, more spaced, and tabulate pseudopaxillæ, larger marginal plates with more numerous spinelets, smaller actinal interradial areas, and especially in having much longer furrow spinules and longer bristling actinal adambulacral spines in a straight transverse series.

Description.—Rays variable in number, but usually eleven or twelve, less often thirteen, ten, nine, or eight. The width varies with the number, being greater when the number is small. Typical specimens have the pseudopaxillæ much larger and more distantly spaced than in *endeca*, tabulate in structure, and resembling superficially in alcoholic specimens the parapaxillæ of *Mediaster*. They are elliptical or roundish in contour, largest on disk and proximal portion of rays, decreasing in size toward the end and sides of rays, being arranged in regular quincunx on the lateral portions of the rays. In *endeca* the pseudopaxillæ decrease in size toward the center of disk, but in *dawsoni* they are subequal, or slightly larger. The paxillæ vary considerably in size in different localities and the number of spinelets and their length is also variable. An example from Monterey Bay has on the larger paxillæ of disk, surmounting the low tabulate eminence of the plate, sixteen to thirty peripheral and five to fifteen central, short, rough-tipped stubby spinelets so immersed in membrane that only the tips protrude and give a granuliform appearance, the summit of the group being usually flat. The spinelets themselves are longer than the height of the tabulum, and usually but not always shorter than width of large paxillæ. A variety from deeper water (stations 3459, 3466) has the paxillæ more convex and the spinelets more diverging, and less compact. The spinelets are sometimes much less numerous, ten to twenty to a paxilla. Papulæ numerous in the meshes of the skeleton, five to ten or even more on disk and usually one to five on rays except distally where there are only one or two. Very large specimens may have as many as twenty papulæ to an area near center of disk.

Marginal plates numerous, separated by their length or less; larger than in *endeca*, the inferomarginals being slightly higher and with fifty or more spinelets, the inferior of which are much the longest, and exceeding the height of the pedicel, the others graduated in length toward the upper end of the plate, being there about the same height as on the paxillæ. In shallow water specimens the pedicel is no higher than in *endeca*, although certain examples from deeper water (as for instance, station 3466) have higher marginals and are not typical in respect to the abactinal paxillæ which are convex, not flat-topped. Typically the superomarginals are larger than in *endeca* and are larger than the immediately adjacent abactinal paxillæ, having about twenty peripheral and ten to twelve central spinelets, but the number is variable, like every other character. Sometimes the superomarginals are directly above the corresponding inferomarginals, but sometimes they alternate, both arrangements being found on the same ray.

Adambulacral spines long and bristling, the furrow series especially being much longer than those of *endeca*. Furrow spines stout, though slender, tapering, bluntly pointed, skin-covered, united basally by a web, three or four in number (on the first adambulacral, five or six). Actinal series straight (occasionally very slightly curved) containing five or six subequal, tapering, stout, bluntly pointed, or chisel-tipped spines, the innermost equal to or a little longer than the furrow spines, the others successively slightly shorter. The innermost spine does not stand out of line and aborad to the rest, nor is the series conspicuously curved as in *endeca*, except sometimes at base of ray. The straight actinal series will serve to distinguish this from other closely related forms. These actinal spines, when erect, extend conspicuously beyond the level of the marginal paxillæ.

Mouth plates broader than in *endeca*, even when the rays of the latter are less numerous. Marginal spines nine to eleven, the outer ones conspicuously longer than in *endeca*, being subequal to the adambulacral furrow spines (these being short in *endeca*). The inner four or five are still larger, the innermost equaling or exceeding the interradial dimension of the plates. The actinal surface bears a single or double row or group of five to ten prominent spines, the inner longest; or only one or two spines. There seems to be great variability in this character.

Actinal interradial areas very small in typical shallow water examples and containing about twenty to twenty-five plates bearing a circle or group of about six to twelve webbed spinelets much longer than those of dorsal paxillæ and about equaling or slightly exceeding the longest inferomarginal spinelets. The variety from stations 3466 and 3459, having ten and eleven rays, has decidedly larger than typical interradial areas, as has also an eight-rayed specimen from station 4247. In these the number of plates to an area is upward of sixty-five. As scarcely two specimens in the collection are alike and the variations do not seem to be related to locality, no varieties have been named.

Madreporic body conspicuous, midway to margin (or nearer center of disk) and bearing several paxillæ near or on its margin; striæ irregular.

Color in life, reddish brown above and yellow beneath (J. C. Brown, from a specimen taken at Postelsia Point, Renfrew District, Vancouver Island, British Columbia). A specimen from Friday Harbor, Washington, in formalin, is grayish brown above, shading to lighter grayish buff on sides and dull yellowish brown on actinal surface. Mr. Weymouth states that the life colors are similar, but brighter.

Cotype.—In the Yale University Museum.

Type-locality.—Virago Sound, British Columbia, 8 to 15 fathoms.

Distribution.—Monterey Bay, California, to the Aleutian Islands, thence to Kuril Islands; through Bering Strait to Point Franklin.

Specimens examined.—Twenty-eight, from the following localities:

Specimens of Solaster dawsoni examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2879	Off Cape Flattery, Washington	34	rocks	1	U. S. Nat. Mus.
2881	do	24	gray sand	1	Do.
3214	South of Unimak Island, Alaska	38	gray sand, gravel	1	Do.
3216	do	61	black sand, mud	1	Do.
3459	Admiralty Inlet, Washington	123	gray sand	1	Do.
3462	do	92	dark sand, rocky	1	Do.
3466	do	56	gray sand, shells	4	Do.
	Straits of Fuca, Washington			1	U. S. Nat. Mus., D. S. Jordan.
	Cape Mendocino, California			1	U. S. Nat. Mus., Lieut. Commander H. E. Nichols.
	Sanborn Harbor, Shumagins, Alaska.	Lowest water.		1	U. S. Nat. Mus., W. G. Hall (W. H. Dall).
	Point Franklin (10 miles west), Alaska.	13½	sand	2	U. S. Nat. Mus., Point Barrow Expedition.
4247 [a]	Kasaan Bay, Prince of Wales Island, southeast Alaska.	89-114	green mud, fine sand	1	*Albatross*, 1903.
4777 [b]	Near Semisopochnoi Island, Aleutians.	52-43	fine gravel	1	*Albatross*, 1906.
4778 [b]	do	43-33	fine black gravel	3	Do.
4804 [b]	Simushir, Kuril Islands	229	coarse pebbles, black sand	3	Do.
	Monterey Bay, California	Offshore[c].		2	Stanford University.
	Renfrew District, Vancouver Island, British Columbia.	Low tide.		1	Stanford University, J. C. Brown.
	Friday Harbor, San Juan Islands, Washington.	do		2	Stanford University, F. W. Weymouth.

[a] Eight-rayed, large actinal interradial areas.

[b] Variety, some with eight rays, resembling somewhat *S. paxillatus;* possibly hybrids.

[c] Brought up on fishermen's lines; less than 70 fathoms.

Remarks.—This species may be distinguished from both *endeca* and *stimpsoni* by the long furrow spines, which are nearly as long as the actinal spines, by the straight or nearly straight comb of the latter, and by the larger, usually flat-topped pseudopaxillæ.

SOLASTER PAXILLATUS Sladen.

Pl. 87, figs. 1, 2; pl. 88; pl. 89, figs. 1, 2; pl. 113, fig. 3.

Solaster paxillatus SLADEN, *Challenger* Asteroidea, 1889, p. 452, pl. 71, figs. 1-3; pl. 72, figs. 1, 2.

Diagnosis.—Rays eight to ten. $R = 177$ mm.; $r = 58$ mm.; $R = 3 + r$; varying to 3.7 r. Disk moderate to large; rays, stout; no marked interradial streak free from paxillæ as in *borealis*, but a slight indication in some specimens; paxillæ fairly close-set, subtabulate with numerous small spinelets heavily invested with membrane; paxillæ not so widely spaced as in *borealis*, nearly as in *dawsoni;* on the rays and peripheral portion of disk about their own diameter apart, more crowded on center of disk; marginal plates in two series, the superomarginals about the size of larger paxillæ, and standing above and between the prominent fan-shaped inferomarginal paxillæ; latter with constricted base and semicircular summit bearing numerous spines decreasing in size toward upper end; adambulacral furrow spinelets long, four or three, then three, two, and finally one at end of ray; actinal series curved aborad at inner end and with proximally five to eight, distally three to five longer slender spinelets; mouth plates with eight to eleven marginal and about fifteen suboral spines.

Description.—Abactinal paxillæ very numerous, low, tabulate (similar to those of *dawsoni*), with a roundish crown of numerous very short denticulate spinelets immersed in membrane. On the disk the paxillæ are not very uniform in size, and larger toward center, where they are spaced less than their own width. On the peripheral half of the disk and on rays the paxillæ are not so close together, but are spaced about their own width apart or slightly more. Here they are arranged in very oblique transverse rows, and also in fairly even cross rows, but a longitudinal arrangement is not so evident (so-called quincunx order). The larger paxillæ of disk have thirty to forty thick, fleshy spinelets forming a slightly convex crown, the peripheral series of ten to fifteen being the largest, the rest decreasing in size toward center. On the proximal part of the ray the paxillæ have about the same number of spinelets, but the whole paxilla is smaller, and they decrease regularly in size toward tip of ray and to a less extent toward the margin. The spinelets are less heavily enveloped on the ray. The spinelets themselves are slender, even on the disk, with numerous denticles at the tip. An undried paxilla is about as high as the width of the crown of spinelets; when dried, slightly higher.

Abactinal plates along lateral area of ray regularly four-lobed, each plate imbricating with four others by the length of a lobe, the regular meshes thus formed containing one, two, or near median area, three papulæ. Along midradial line and center of disk (out about to madreporic plate) the plates are very irregular, having three, four, or five lobes, and the primary plates on disk are irregularly connected by oblong or irregular ossicles forming very irregular and unequal meshes which contain two to five papulæ. Along midradial region there are two or three to a mesh.

Marginal plates in two series, and of very unequal size, the superomarginals alternating with inferomarginals. Superomarginals considerably larger than adjacent abactinal paxillæ, and about as large as largest paxillæ of corresponding midradial region. Each plate stands opposite the interval between two inferomarginals, and on a level with the upper edge of the latter (not crowded between). Inferomarginals (about sixty to a ray) large, paxilliform, with a much compressed fan-shaped pedicel with a curved outer border or summit bearing thirty to forty spinelets, which decrease very rapidly in length from the lower ones, which are in two series and about as long as half the width of summit of pedicel, to the upper which are in three or four series and the same size as spinelets of abactinal and superomarginal paxillæ. Inferomarginals spaced about their own height apart (but in a variety are closer) and usually are not visible from above, on inner half of ray. They do not extend inward from the margin any great distance on the interbrachial arcs, being there smaller and closer together. They differ from the marginals of *borealis* in having much more numerous and shorter spinelets, in having a relatively higher pedicel, with a more evenly semicircular edge and much more contracted base, in not forming a conspicuous marginal fringe as in *borealis*, and in being more numerous and closer together. They differ from those of *dawsoni* in being higher, with a more convex or semicircular edge, and in being more widely spaced.

Adambulacral plates of the same general type as in *dawsoni*. Furrow spines long, at base of ray three or four, then three (the adoral becoming shorter and shorter), then two, and finally, near the end of ray, only one. The spines are slender and webbed at the base, the outer part having a flange of tissue, and the middle spine is longest, about as long as the distance between the inner end of two adjacent actinal series. Subambulacral spines (proximally five to eight, distally five, four, or three) longer, tapering, pointed, similarly webbed and membrane-sheathed, in a transverse series the inner end of which bends aborally so that the inner spine is opposite the aboral furrow spine while the outermost is at the adoral edge of plate. These spines are slenderer than in *borealis*, stand on a ridge of the plate and are subequal in length, or the outermost shortest, and in length about equal the base line of the series, or the distance between the inner end of three adjacent actinal series or slightly more than the combined length of two adambulacral plates. The maximum number of spines in the largest specimen is six; in a smaller example, eight. In *dawsoni* the actinal comb is straight, not curved, as in this species.

Mouth plates similar in form to those of *borealis*, with eight to eleven marginal, and upward of fifteen suboral spines on each. The former increase very markedly in length at inner angle, the inner three or four being long, the innermost as long as the interradial diameter of combined plates. The suborals usually form a crowded series with those of the companion plate, the innermost being nearly as long as the teeth, the outer rapidly shortening or forming two or three series parallel to suture.

Actinal interradial areas larger than in *borealis* and much larger than in *dawsoni*, with spaced low pseudopaxillæ in chevrons, bearing a variable number, but usually numerous (as few as five, as many as fifteen) slender spinelets united at the base by membrane. A single series of small intermediate plates bearing one to few spinelets extends over half the length of ray.

Madreporic body halfway between margin and center of disk, surrounded and partly obscured by five to eight large paxillæ.

Variations.—The specimens from stations 4792, 4784, 2853, and 3223 constitute a well-marked variety with eight rays. The number is usually nine (station 3331), less often ten; specimens from 3500 are either eight-, nine-, or ten-rayed; the eight-rayed being similar to those from 2853 and 4784, the others resembling examples from 3331. The eight-rayed variety (pl. 89), as compared to the form from station 3331 (pl. 87), has broader rays, more compactly placed paxillæ, with more numerous spinelets and larger superomarginal paxillæ, which usually stand above the inferomarginals rather than opposite the interval between. The inferomarginals in extreme examples are closer together, and both series have more spinelets, which may or may not be shorter than in specimens from 3331. In the variety, also, the actinal spinelets are more heavily invested with membrane and the actinal adambulacral spines are more numerous (eight or nine proximally). The suboral spinelets form a dense cluster on each plate. In extreme cases the actinal interradial area is smaller (pl. 89, fig. 2), with relatively larger and fewer paxillæ. The general appearance of the actinal surface is that of more dense spinulation and more compact marginals. The specimen from 2853 (pl. 89, fig. 1), however, although typical of this variety abactinally, has an actinal surface similar to specimens from 3331, and thus combines characters of each form. The specimens from 3500 also belong to both forms. The superomarginal paxillæ present gradations between the two extremes.

The specimen from 4784 is an extreme example of the variety with unusually large superomarginals. It resembles aberrant specimens of *S. dawsoni*, but is probably referable to *paxillatus* as the actinal combs of adambulacral spines are curved, not straight, as in *dawsoni*.

It is certainly very tempting to consider this variety a distinct species, but the evidence of intergradation can not be ignored. There is a possibility that the variety is really a northern form, which is hybridizing with true *paxillatus*, derived from the south.

Type.—British Museum.

Type-locality.—South of Yokohama, Japan, *Challenger* station 232, 345 fathoms, green mud.

Distribution.—From south of Yokohama, Japan, to Bering Sea, thence to vicinity of Kadiak Island, Alaska, 56 to 350 fathoms; the typical form in deeper water.

Specimens examined.—Twenty-two, from the following localities:

Specimens of Solaster paxillatus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2853	South of Kadiak Island, Alaska	159	gray sand	1	U. S. Nat. Mus.
3223	Off Unimak Island, Alaska	56	black pebbles	2	Do.
3331	North of Unalaska	350	mud	6	Do.
3500	South of St. George Island, Bering Sea.	121	fine gray sand	7	Do.
3608	Bering Sea, between St. George and Unalaska.	276	gray sand	3	Do.
4784	Near Attu Island, Alaska	135	coarse pebbles	2	*Albatross*, 1906.
4792	Off Commander Islands	72	pebbles	1	Do.

Remarks.—This species differs from *dawsoni* in having more prominent and typically more widely separated inferomarginals, and in having the superomarginals alternating with the inferomarginals. The actinal interradial areas are much larger than in *dawsoni*, and the actinal comb of adambulacral spines is curved at the inner end, while in *dawsoni* it is nearly or quite straight.

From *S. borealis*, *paxillatus* differs in having much larger abactinal paxillæ, in lacking the bare interradial streak, in having more numerous inferomarginals, with much shorter spinelets, in having distinguishable, even prominent superomarginals, and fairly long furrow spinelets.

A specimen from station 5050, off Honshu, Japan, while differing from Alaskan specimens in having rather smaller paxillæ, seems to be referable to the form from station 3331. At the same time it does not appear to be separable from Sladen's *S. paxillatus*. The Alaskan examples have therefore been ranked under *paxillatus* which, if the identification is correct, has a fairly wide range and is extremely variable.

The stomach of one specimen contained a holothurian, *Molpadia intermedia*.

SOLASTER EXIGUUS Fisher.

Pl. 90, figs. 1, 2; pl. 112, figs. 4, 4*a–b*.

Solaster exiguus FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 573.

Diagnosis.—Similar in general appearance to *S. paxillatus*, but disk smaller, paxillæ smaller, inferomarginal plates more widely spaced and much narrower with fewer and longer spinelets, actinal interradial areas smaller (despite the fewer rays); furrow spinelets two or one, long; actinal adambulacral spinelets three to five. Rays seven; R = 25 mm.; r = 8 mm.; R = 3 r.

Description.—Rays moderately slender, the inferomarginals not visible from above except on outer part of the ray. Paxillæ rather small (but not so small as in *endeca* or *borealis*), and spaced farther than their width. They have the appearance of being fairly well spaced, although the papular areas contain ordinarily but one papula. Paxillæ arranged in quincunx on the rays, definite longitudinal and oblique transverse rows being discernible. Each paxilla consists of a cruciform base raised into a low tabulum surmounted by five to eight or even ten slender spinelets considerably longer than height of tabulum and with denticulate blunt tips. When the spinelets stand erect the paxillæ appear small and well spaced, but when the spinelets are spread out the paxillæ nearly touch one another and look much larger. When spread out the spinelets are seen to be webbed for half their length.

Inferomarginal paxillæ similar in general appearance to those of *borealis*, well spaced, two to every three adambulacral plates, hence spaced farther than the width of a paxilla. Each inferomarginal is subcircular, only very slightly compressed and is crowned by five to twelve delicate spinelets, longer than the pedicel and denticulate at tip. Above the interval between two inferomarginals is a small superomarginal similar to but slightly larger than adjacent abactinal paxillæ. This is less conspicuous than in *paxillatus*.

Adambulacral armature prominent; plates well spaced as in *borealis*. Furrow spinelets unusually long, nearly or quite as long as the actinals; proximally two, and distally 1. Actinal comb slightly curved aboral at inner end, and consisting of three to five slender long spinelets webbed basally, the middle spinelets longest.

Actinal interradial areas smaller than in *paxillatus* and *endeca*, about as in *borealis*, and containing fifteen to twenty paxilliform groups of five or six spinelets.

Mouth plates rather small, with six to eight marginal and two to five suboral spinelets, the former webbed basally and the inner two or three enlarged into teeth.

Madreporic body small, situated at about the middle of r.

Type.—Cat. No. 27786, U.S.N.M.

Type-locality.—*Albatross* station 2980, off Anacapa Island, California, 603 fathoms, green mud, two specimens. Known only from this locality.

Remarks.—Although this species was dredged along with *S. borealis* and *Heterozonias alternatus* it is clearly not referable to either. It is probable that the number of rays varies from the small number of seven in the types. It is at once distinguished from *H. alternatus* in lacking the characteristic superomarginals of that species, and it differs from *borealis* in having larger paxillæ with more numerous longer spinelets (the paxillæ being consequently higher), more numerous and delicate inferomarginal spines, more prominent, alternating superomarginals, and two long furrow spinelets (not five or six short ones). It may be separated from *paxillatus* by the much smaller actinal interradial areas, differently formed, and more widely separated marginals which have longer spinelets, by the few suboral spinules and typically smaller paxillæ with fewer and longer spinelets. It is not possible to determine whether intergrades exist between *exiguus* and *paxillatus*.

SOLASTER BOREALIS (Fisher).

Pl. 91, figs. 1-3; pl. 92, figs. 1, 2; pl. 113, figs. 2, 2*a*.

Crossaster borealis FISHER, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 134.

Diagnosis.—Rays nine to twelve, very rarely thirteen. R=140 mm.; r=47 mm.; R=3 r. Breadth of ray at base, 23 mm. Closely resembling *Solaster australis* (Perrier). Marginal plates in a single series, very prominent, spaced, paxilliform, with prominent bristling spines, and situated on the margin of ray, becoming actinal in position only in interbrachial angle and then at the ambitus. Abactinal pseudopaxillæ very small and spaced with very few spinelets. Papulæ large, when fully extended larger than paxillæ which they often obscure in big specimens, one to three to a mesh on ray, three to ten on disk. Madreporic body exposed. A bare interradial streak extending from the interbrachial angle half way to center of disk. Adambulacral plates with five or six furrow spinelets (varying to three or four distally and as many as eight proximally), and two, three, four, or five very much longer and stouter actinal spines, in a transverse series. Mouth plates with about eleven furrow spinelets and only one or two small suboral spinelets, sometimes none; inner oral spines much lengthened. Actinal interradial areas small, the spaced paxillæ with few spinelets; a single row of actinal intermediate plates extending far along ray.

Description.—Abactinal integument entirely obscuring underlying skeleton, unless dried or treated with caustic potash. Paxillæ small, spaced, with a low tabulum surmounted by one to six slender blunt or pointed, tapering spinelets. In life these spinelets are thick, short, and stubby, owing to a membranous investment, and are usually three or four to each paxilla. In center of disk and along distal half of ray, paxillæ irregularly arranged, but between these two areas an arrangement in longitudinal rows more or less evident. Base of paxillæ with three or four slender unequal lobes impinging upon those of neighboring paxillæ or connected by short irregular ossicles; latter not numerous; near center of disk there are one or two isolated ossicles in many of the meshes. Anus surrounded by four or five large paxillæ. As in preceding species a very narrow bare sulcus extends from interradial angle about half way to center of disk. Papulæ prominent, but usually not quite so large as in preceding species, about three to ten to a mesh on disk, one to three in distal half of ray where skeleton is closer.

Marginal plates very prominent, spaced, in a single series, about twenty to thirty on each side of a ray and confined to the margin. Superomarginals not different from abactinal paxillæ and indistinguishable from them as a rule. Inferomarginals with fairly high pedicels (relatively about as in *papposus*), bearing two vertical or transverse palmate series of six to nine stout tapering pointed skin-covered spines, the mesial of which are the longest. Sometimes there is one main series, and two or three smaller spines stand adorally out of the series, or there may be a second adoral series of less conspicuous spinules, but few in number. Spines of proximal plates shorter than rest, except near tip of ray. The spines vary in length but are about as long or a third longer than the extreme width of the top of the pedicel and often twice as long as its height. The distance between the top of two adjacent marginal plates is slightly less to one-third greater than the extreme height of pedicel and longest spine. The prominent bristling spaced marginal paxillæ form one of the characteristic features of this species.

Actinal interradial areas rather small, about thirty-five to forty plates to each area. Plates obscured by integument which has fine furrows or wrinkles leading from interadambulacral sulcuses to marginal plates. Plates appear spaced, each bearing one to four short stubby papilliform spinelets, very delicate when dried. Plates arranged irregularly in rows, between the wrinkles. A series of very small widely spaced actinal intermediate plates extends over three-fourths length of ray. They bear usually one or two stumpy spinelets, or are spineless.

Adambulacral plates with (1) a palmate furrow series of five or six (distally three or four) slender tapering skin-covered spinelets (united for about half their length by a web) of which the second or third mesial are subequal, the laterals much shorter. These spinelets are of about same length as in *Heterozonias alternatus* and about as long as the base line of comb. On the proximal part of ray in some specimens there are seven or eight spinelets to a furrow comb. (2) On actinal surface is a transverse series of four (three on smaller examples, varying to two and five) much longer, slender, terete, blunt, skin-covered spines, the second or third usually longest (exceeding in length the width of plate), the outer about one-half length of inner (where there are three spines); when two spines only are present they are subequal and long. The longest spines are about twice as long as the longest furrow spinelet.

Mouth plates just a trifle narrower than in *H. alternatus*. Free margin with a webbed series of about eleven spinelets increasing in length toward inner end of each plate to two or three much enlarged spines, the innermost stoutest. On actinal surface of plate near inner end of each is a stout, though slender, spine. Sometimes instead of this a small one stands on outer end of plates, or there may be two or three small spines, or the surface may be entirely unarmed. The furrow spinelets are usually eleven, but vary to nine or twelve even in otherwise typical examples. The mouth plates are decidedly narrower in specimens with twelve rays than in those with nine (station 3607).

Madreporic body variable in size, exposed and situated at inner end of an interradial sulcus. Two or three large paxillæ stand near it.

Color in life, of a Californian specimen: Abactinal surface, dull orange or saturn red; dull light yellow below.

Variations.—All the specimens from station 3607 have nine rays, which are broader than in the type. There seem to be no important constant differences in the ornamentation however. Specimens with ten and eleven rays are present in the collection but nine and twelve are the prevalent numbers. Size has apparently nothing to do with the number of rays. Variations in the number of furrow spines and subambulacral spines have been alluded to in the description. The increased number of furrow spines can not be correlated with other constant differences. Certain specimens, especially those from station 3607, have curious slits in the web at the base of the furrow spines of mouth and adambulacral plates. Examples with fewer rays have the paxillæ more widely spaced than those with eleven or twelve rays. Owing to the broader mouth angles in examples with nine and ten rays, the mouth plates are broader than in specimens with twelve rays.

Specimens from California to Queen Charlotte Islands have a different appearance from the more northern examples and perhaps deserve to be separated as a race of typical *borealis*. The abactinal paxillæ are lower, both the spinelets and pedicels being shorter, and the spinelets blunter, the rays are often slender (ten to twelve in number), the marginal paxillæ have rather fewer spines and the subambulacral spines are only two or three and less heavily covered with membrane. Oral spines eleven to thirteen, the suborals are one or two, or absent. The differences are most pronounced in the specimen from station 4415 between Santa Catalina and Santa Barbara Islands, 638 fathoms.

I have examined a twelve-rayed specimen from station 5050 off the east coast of Honshu, Japan (lat. 38° 11′ 30″), 266 fathoms. The rays are shorter than in typical examples ($R=52$ mm., $r=22$ mm., $R=2.36$ r). A nearly equal-sized specimen from Monterey Bay has $R=2.7$ r. There is a thirteen-rayed specimen from station 3489, Bering Sea, which has $R=2.1$ r. The length of ray is therefore variable even in typical examples. The most important difference is the small number of three furrow spinelets throughout most of the furrow. There are nine oral and one to three suboral spines. The paxillæ are fairly typical with two to four or five tapering spinelets. The bare interradial streaks or lines are well marked.

Type.—Cat. No. 21933, U.S.N.M.

Type-locality.—*Albatross* station 2858, east of Kadiak Island, Alaska, in 230 fathoms, on blue mud and gravel.

Distribution.—From off San Diego, California, to Bering Sea, thence to Honshu, Japan, 225 to 1,044 fathoms.

Specimens examined.—One hundred and seven, from the following stations:

Specimens of Solaster borealis examined.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms.			
2858	East of Kadiak Island, Alaska	230	blue mud, gravel	1	U. S. Nat. Mus.
2860	South of Queen Charlotte Islands	876	green mud	7	Do.
2871	Off Gray's Harbor, Washington	559	brown ooze	1	Do.
2937	Off San Diego, California	464	green mud	2	Do.
2980	Off Anacapa Island, California	603	do	5	Do.
3070	Off Sea Lion Rock, Washington	636	do	2	Do.
3071	do	685	do	6	Do.
3073	do	477	do	1	Do.
3075	do	859	do	15	Do.
3126	Monterey Bay, California	456	do	1	Do.
3227	Bering Sea north of Unalaska	225	do	1	Do.
3331	North of Unalaska	350	mud	1	Do.
3337	South of Unimak, Alaska	280	green mud	2	Do.
3338	South of Shumagin Islands, Alaska	625	do	2	Do.
3343	Off Destruction Island, Washington	516	do	16	Do.
3346	Off Tillamook Bay, Oregon	786	do	1	Do.
3347	do	345	mud	2	Do.
3489	Bering Sea, west of Pribilof Islands	184	green mud, gray sand	1	Do.
3601	Bering Sea, south of Pribilof Islands	1,044	green mud	1	Do.
3607	North of Unalaska	987	green mud, black lava sand	28	Do.
3608	Bering Sea, between Pribilof Islands and Unalaska.	276	gray sand	1	Do.
3670	Monterey Bay, California	581	green mud sand	6	Do.
4415	Between Santa Catalina and Santa Barbara Islands, California.	131–638	green mud	1	*Albatross*, 1904.
4420	Between Santa Barbara and San Nicholas Islands, California.	238	black mud	1	Do.
4528	do	545–800	soft gray mud	2	Do.

Remarks.—The differences between *borealis* and *hypothrissus* will be found below under that species.

The species to which *borealis* (and especially the Californian form) shows the greatest resemblance is Perrier's *Crossaster australis* from the Straits of Magellan. The differences are evidently not great and it is not at all improbable that the ranges of the two will some day be found to run together. The west coast of South America is not as yet well worked in deep water. *Crossaster neptuni* Bell may be a link in this chain. *Solaster australis*[a] differs in having a single papula[b], not several, in each mesh of the skeleton, especially on disk; in having a series of suboral spines (as in *hypothrissus*); and in having less prominent marginal plates with shorter spines. There seem to be differences in the paxillæ, judging by Perrier's figure, but it is perhaps not safe to make comparisons without specimens. *Australis* has nine or ten rays which are about as slender as in Californian specimens of *borealis* though longer (R = 3.25 r).

Solaster regularis Sladen, collected by the *Challenger* in 175 fathoms, south of Wellington Island, off Chile (lat. 50° 08′ 30″ S.), is another closely related species, and its relationship with *australis* is greatly in need of elucidation. If *regularis* is only a variant of *australis*, the remarks made above concerning the differences between *australis* and *borealis* will have to be emended. Sladen refrains from stating how many specimens he had (a defect of practically all his descriptions), so that it is not possible to judge of the range of variation. *Regularis* has only eight rays, which are unusually long (R=4.5 to 5 r), broad stumpy paxillæ with six to ten spinelets, less markedly compressed marginal plates, with more numerous and apparently shorter spines, less prominent actinal adambulacral spines (four or five in number), and a row of five suboral spines.

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[a] See Ludwig, Zeitschr. für wiss. Zool., vol. 82, 1905, p. 65.

[b] Perrier, Miss. sci. Cap Horn, 1891, p. 115, pl. 10, fig. 1c.

SOLASTER HYPOTHRISSUS Fisher.

Pl. 93, figs. 1, 2; pl. 113, figs. 5, 5*a*.

Solaster hypothrissus FISHER, Zool. Anz., vol. 35, March 29, 1910, p. 574.

Diagnosis.—Similar in general appearance and structure to *S. borealis*, but differing in having a row of five to seven prominent suboral spines parallel to the median suture, in having a maximum of six long subambulacral spines, instead of four or less, and in having the abactinal pseudopaxillæ slightly higher with seven to nine spinelets which are blunter than in typical *borealis* and end in several points, not in an attenuate denticulate tip. Rays ten. R=118 mm.; r=38 mm.; R=3 r+.

Description.—It is not possible to determine whether this is a distinct species or a "form" of *borealis*. A close examination reveals many points of intimate resemblance to *borealis*, but no intermediate specimens have been found. The chief features have been alluded to in the diagnosis. The papulæ are prominent, as in *borealis*, but the paxillæ are stouter with more spinelets (seven to nine instead of three or four). The spinelets are less attenuate distally and form a rosette with one in the center. There are about thirty marginal plates not differing in any important respects from those of *borealis*. The actinal intermediate plates extend in a single series nearly to end of ray; distally they are very inconspicuous. The adambulacral armature is very bristling, the actinal series containing proximally six spines, the outer the shortest, and distally five, then four. The furrow series has only three to five spinelets, five proximally, which are webbed for about half their length. They do not differ in important respects from those of *borealis*, but are slightly longer. The mouth plates and their armature depart more widely from those of *borealis*, having a bristling array of suboral spines five to seven in a row parallel with and close to the suture. The innermost spine is the stoutest and about as long as the longest actinal spine of the first few adambulacral plates. The marginal spines are rather longer than in *borealis*, especially the outer ones.

Type.—Cat. No. 27787, U.S.N.M.

Type-locality.—Station 3338, south of the Shumagin Islands, Alaska, 625 fathoms, green mud, two specimens.

Distribution.—Vicinity of the Aleutian Islands.

Specimens examined.—The types and one specimen from station 4784, near Attu Island, 135 fathoms, coarse pebbles.

Remarks.—It is a matter upon which opinion may well differ whether such a form as *hypothrissus* should be dignified with a name. The structure of the mouth plates and paxillæ is different from that of typical *borealis*. The former are among the least variable parts of this variable genus, and may be relied upon perhaps more safely than the adambulacral armature. The armature of the mouth plates is variable, to be sure, but the limits are less wide than in the case of the adambulacral or marginal plates, and they change much less with age. The general facies of the two species is quite unlike.

SOLASTER PAPPOSUS (Linnæus).

Pl. 94, figs. 1–6.

Asterias papposa Linnæus, Syst. Nat., 12th ed., 1767, p. 1098.—O. F. Müller, Zoologiæ Danicæ Prodromus, 1776, p. 234.—Fabricius, Fauna Grœnlandica, 1780, p. 369.

Asterias helianthemoides Pennant, British Zoology, vol. 4, 1777, p. 56.

Asterias affinis Brandt, Prodromus, 1835, p. 71. (Bering Strait.)

Stellonia papposa Agassiz, Mém. soc. sci. nat. Neuchâtel, vol. 1, 1835, p. 192.

Solaster papposa Forbes, Mem. Wernerian Soc., vol. 8, pt. 1, 1839, p. 121; British Starfishes, 1841, p. 112, fig.

Solaster (*Polyaster*) *papposa* Gray, Ann. and Mag. Nat. Hist., vol. 6, 1840, p. 183.

Crossaster papposus Müller and Troschel, Monatsber. preuss. Akad. Wiss. Berlin, Apr., 1840, p. 103; Archiv Naturgesch., 6 Jahrg., vol. 1, 1840, p. 183.—Murdoch, Marine Invertebrates, Report of the International Polar Expedition to Point Barrow, Alaska, 1885, p. 159.—Ludwig, Fauna Arctica, vol. 1, 1900, p. 460 (Review of literature and synonymy to 1900).

Solaster papposus Müller and Troschel, System der Asteriden, 1842, pp. 26, 127; pl. 3, fig. 1 *a–b*; pl. 12, figs. 3, 4.—Dujardin and Hupé, Hist. nat. zoophytes, Échinodermes, 1862, p. 353.—Perrier, Révision des Stellérides., 1875, p. 94.—Döderlein, Wiss. Meeresuntersuchung, neue Folge, vol. 4, Abth. Helgoland, Heft 2, 1900, p. 205, pl. 6, figs. 1–4.—Östergren, Zool. Anz., vol. 27, 1904, p. 615.—Grieg, Bergens Museums Aarbog, 1906, No. 13, pp. 46–66, text figs. 7 (4) fig. 8; pl. 1, figs. 6–8.

Diagnosis.[a]—Rays eight to fourteen, usually ten or eleven, very rarely less than nine or more than thirteen; in the North Pacific, commonly ten or eleven. R = 1.8 to 2.3 r. Rays stout, tapering; abactinal skeleton forming an open reticulate structure with widely spaced penicillate paxillæ and numerous intervening papulæ. Paxillæ with stout pedicels and upward to fifty slender spinelets graduated in length from periphery to center, the latter spinelets being typically as long as or longer than pedicel (in some varieties shorter). Marginal paxillæ in a single series, well spaced, prominent, similar to but usually larger than the abactinal. Adambulacral plates with usually three or four, three to five, four or five, or rarely four to seven furrow spinelets in a comb, and a transverse actinal comb of about five to nine slightly longer and stouter spinelets. Interradial paxillæ none to about twenty-five, varying in different interradii; mouth spinelets, about eight to ten marginal and two to four suborals.

Notes on North Pacific specimens.—The variability of *Solaster papposus* has been described and figured by several authors, especially Döderlein[b] and Grieg,[c] who have confined their attention to examples from the North Atlantic and adjacent portions of the Arctic Ocean. The North Pacific specimens are also variable, so much so, in fact, that the extremes are very unlike. The species tends to form small varieties differing with locality and also with depth, but there are instances where the same variation (or nearly the same) is repeated in widely separated places. The forms listed herewith as *Solaster papposus* may in reality be small species, but it has not been possible to separate them on account of intergrades. With the exception of the Japanese specimens, which are believed to constitute a distinct species, all the North Pacific varieties have been called *Solaster papposus.*

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[a] "Similis A. rubenti, sed radiis 13; undique muricata aculeis apice pectinatis s. fasciculatis." Linnæus.

[b] Wiss. Meeresuntersuchung, neue Folge, vol. 4, Abth. Helgoland, Heft 2, 1900, p. 205, pl 4, figs. 1–4.

[c] Bergens Museums Aarbog, 1906, No. 13, pp. 46–66. For a discussion of variations in *Solaster papposus* and *S. squamatus*, as well as for a review of the literature, this article is quite complete.

Variety A.—One of the most striking varieties is that from Point Franklin, Bering Island, Kadiak, and Sakhalin. (A complete list of stations given in record of specimens.) In this the rays are ten, less often eleven, short, and robust. The paxillæ are lower than in typical *papposus,* globose, the spinelets being much shorter. In this form the central spinelets of a paxilla are relatively short, the whole paxilla being about as high as broad, while in typical *papposus* the central spinelets alone are longer than the width of a paxilla. The midradial paxillæ are larger than the rest and form a fairly straight series. The abactinal skeleton is decidedly of the reticulate form characteristic of *papposus* and not closely imbricated[a] as in *S. squamatus* (Döderlein). The marginal paxillæ likewise have much shorter spinelets and pedicels, showing about the same relative difference from the typical form as do the abactinal paxillæ. Adambulacral plates with three or four moderately long skin-covered and partly webbed spinelets, the adoral when there are four being shorter than the rest. In the transverse subambulacral series are six or seven tapering spinelets, equaling or slightly exceeding the furrow spinelet. The inner end of the series curves aborad. Mouth plates with six or seven marginal and three or four suboral spinelets. Actinal interradial areas with two to twelve small tufts of short spinelets. In general appearance this variety departs farthest from the type, especially on account of the low globose paxillæ. I have examined a specimen from station 5024, Okhotsk Sea, off the east coast of Sakhalin, vicinity of Cape Patience, which is referable to this variety. The largest specimen (station 4795) measures: R=66 mm.; r=35 mm.; R=1.86 r. In this the midradial row of paxillæ is not quite so prominent as in smaller examples, but the rays are thick and the interradial areas unusually large. (See pl. 94, figs. 4, 5.)

Two specimens from station 3231, having eleven and twelve rays, are intermediate between variety A and typical *papposus.* The abactinal surface is nearly as in A, but the numerous rays, reduced actinal interradial areas, and longer adambulacral spinelets are more like the typical form.

Variety B.—From stations 4777 and 4778 are four specimens which show a combination of the characters of variety A and variety C, and are only slightly different from typical *papposus.* The midradial row of paxillæ is well marked, but all the paxillæ are higher than in variety A, though not so high or so slender as in C. Rays ten or eleven.

Variety C.—This form differs from typical *papposus* in having the midradial paxillæ longer and slenderer and the rays slenderer as a rule. Rays ten or eleven.

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[a] Described and figured by Grieg, Bergens Museums Aarbog, 1906, No. 13, pp. 46-66, text figs. 7, 8; pl. 1, figs. 6-8.

The midradial row of paxillæ is clearly distinguishable from the rest, that is those between the midradial and marginal paxillæ, being relatively smaller than in *papposus*. The paxillar spinelets are long, longer relatively than in most specimens of *papposus*, and the actinal spines are all long. The marginal plates are very prominent. Furrow spines four; superadambulacral spines five or six, as a rule. In general appearance this variety has a more open abactinal skeleton than most specimens of typical *papposus*, and the slenderness of the paxillæ gives a different facies, which is perhaps better appreciated from a comparison of figures. Stations 4787, 4788, 4791, 4792, 2847, and others. (Pl. 94, figs. 2, 3.)

Practically the same variations are present in specimens all the way south to Oregon and Washington, as, for instance, from stations 2848, 2865, 2866, 2874, 2877, 3051, 3445, 3459, 3461, 4286. The southernmost examples (2874, 3051, 3459, 3461) have the variation very well marked. The abactinal skeleton is wide meshed and the paxillæ tall and slender, there being fewer than in typical *papposus*. The midradial paxillæ are sometimes, though not always, as large as the marginals, and are distinctly larger than the dorsolaterals. The actinal spines are long and slender, the adambulacral plates having three or four furrow spines, and four to six or seven in the actinal series. Mouth plates with nine to twelve marginal and two to four suboral spines. If this variety is compared with A, the contrast is of course very striking. In many particulars typical *papposus* is about intermediate between the extremes.

Type-locality.—"Habitat in O. Europæo et Asiatico." (Linnæus.)

Distribution.—Circumpolar; through Bering Straits, into Bering Sea, thence south along the west coast of North America to Washington; on the Asiatic side to the Sea of Okhotsk. Along the east coast of North America, from Newfoundland and Labrador south to about 40° north latitude; northward to Davis Strait and Smith Sound, the northernmost point being reached in Discovery Bay; westward to Assistance Bay in Barrow Strait, thence to Point Barrow; eastward to Greenland, Jan Mayen, Spitzbergen, northward to about 79½°. South along the Scandinavian coast to the coast of Denmark, Holland, and Belgium, and to the Faroe Channel, Scotland, England, and Ireland, reaching the southern limit in the western part of the channel (lat. 48° 30′ N.). From Finmark eastward through Barents Sea to the Murman coast, thence to the Kara Sea and eastward to the Gulf of Khatanga (long. 113° 30′ E.) on the Siberian coast. (Atlantic data from Ludwig, Fauna Arctica.)

Specimens examined.—One hundred and eighty-six. The letters refer to the varieties mentioned in the preceding discussion.

Specimens of Solaster papposus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2843	Unalaska, Alaska	72	pebbles	1	U. S. Nat. Mus.
2846	Near Unimak Island, Alaska	44	gravel	1	Do.
2847C	Vicinity Shumagin Islands, Alaska	48	fine gray sand	1	Do.
2848C	do	110	green mud	1	Do.
2849A, C	do	69	do	2	Do.
2855	Near Kadiak Island, Alaska	69	do	1	Do.
2856	Off Afognak Island, Alaska	68	gray shells	16	Do.
2865C	Admiralty Inlet, Washington	40	pebbles	2	Do.
2866C	Near Flattery Rocks, Washington	171	do	1	Do.
2874C	Off Cape Flattery, Washington	27	rocks and shells	1	Do.
2875C	do	40	do	1	Do.
2877C	do	59	black sand and mud	1	Do.
3051C	Heceta Bank, Oregon	59	coral, broken shells	1	Do.
3213	South of Unimak Island, Alaska	41	black sand	1	Do.
3214	do	38	gray sand	2	Do.
3217C	do	42	black gravel	2	Do.
3218C	do	41	black sand	1	Do.
3220	Near Unalaska, Alaska	34	gravel, broken shells	1	Do.
3222	do	50	black sand, pebbles, shells	1	Do.
3223	do	56	black pebbles	3	Do.
3231A	Bristol Bay, Alaska	12	sand	2	Do.
3232	do	10	pebbles, stones	5	Do.
3233	do	7	sand, pebbles	3	Do.
3234	do	5		9	Do.
3236	do	14	gravel, sand, shells	3	Do.
3277	North of Alaska Peninsula (near Point Moller).	18	gravel, sand, rocks	4	Do.
3445C	Straits of Juan de Fuca, Washington.	100	rocky	2	Do.
3459C	do	123	gravel, sand, pebbles	2	Do.
3461C	do	114	gravel, sand, rocks	1	Do.
3480	Amukta Pass, Aleutian Islands	283	black sand, rocky	1	Do.
3518A	St. Matthew Island, Bering Sea	36	green mud	2	Do.
3595	Admiralty Inlet, Washington	49	gravel, sand, rocky	3	Do.
	Hagenmeister Island, Alaska	8–15		1	Do.
	Alaska C			1	U. S. Nat. Mus., Dr. W. H Jones.
	St. Paul, Kadiak, Alaska			10	U. S. Nat. Mus., W. J. Fisher.
	Kadiak, Alaska			1	Do.
	Sanborn Harbor, Nagai, Shumagin Island.	Lowest water.		1	U. S. Nat. Mus., W. G. Hall. W. H. Dall.
	Round Island, Coal Harbor, Shumagin Islands, Alaska.	Beach.		4	Do.
	St. Paul Island, Alaska			1	U. S. Nat. Mus.
	Popoff Strait, Alaska			3	U. S. Nat. Mus., W. H. Dall.
	Unalaska			1	Do.
	Point Franklin, Alaska A	13½	sand	2	U. S. Nat. Mus., Point Barrow expedition.
	Kadiak, Alaska A	16–25	gravel	1	U. S. Nat. Mus., W. H. Dall.
	Bering Islands A			9	U. S. Nat. Mus., L. Stejneger, N. Grebnitsky.
	A			1	Steamer *Corwin*, 1881, acc. No. 16889.
	A			1	Steamer *Corwin*, 1884, acc. No. 15278, tag 5.

Specimens of Solaster papposus examined—Continued.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms			
	A			2	Steamer *Corwin*, 1884, 15278, tag 6.
	A			2	Steamer *Corwin*, 1884, 15278, tag 10.
	Port Clarence, Alaska A			1	Stanford University.
4246 C	Kasaan Bay, Prince of Wales Island, Alaska.	42-47	green mud	1	*Albatross*, 1903.
4281 C	Chignik Bay, Alaska Peninsula	42	do	1	Do.
4283	do	30-41	black sand	1	Do.
4284 C	do	26-30	green mud, rocks	1	Do.
4286 C	do	57-63		1	Do.
	Yes Bay, Alaska	42		1	*Albatross*, 1905.
4777 B	Near Semisopochnoi Island, Aleutians.	52	fine gravel	7	*Albatross*, 1906.
4778 B, C	do	43	fine black gravel	2	Do.
4784 B	Near Attu Island, Aleutians	135	coarse pebbles	1	Do.
4787 C	Near Medni Island, Commander Islands.	54-57	green sand	3	Do.
4788 C	do	57	do	1	Do.
4791 C	Near Bering Island, Commander Islands.	76	rocky	1	Do.
4792 C	do	72	pebbles	41	Do.
4795 A	South of Petropavlovsk, Kamchatka.	69-48	green sand	1	Do.
5024 A	Off eastern coast of Sakhalin, vicinity of Cape Patience.	67	sand, pebbles	1	Do.

Remarks.—This species is the type of the genus *Crossaster* Müller and Troschel, 1840, recognized by Sladen, Perrier, Ludwig, Kœhler, and numerous other writers. *Crossaster* differs from typical *Solaster* (as for example, *endeca*) in having the abactinal skeleton a reticulate structure with large spaces, the penicillate paxillæ being correspondingly rather widely spaced. The papulæ are numerous in each area. In *Solaster* the skeleton consists of stellate plates forming a close reticulation, the papulæ are few or isolated, and the paxillæ small and more crowded. These differences are not constant. *Crossaster squamatus*,[a] which by some writers is regarded as a variety of *papposus*, does not conform to the generic diagnosis, for the abactinal plates are closely placed, with isolated papulæ, and are less reticulate in arrangement than several species of true *Solaster*. *Solaster borealis* was first described by me as *Crossaster*; the young are obviously *Solaster*, while the large specimens would be classed as *Crossaster*. The difference in the paxillæ is all that is left to distinguish *Crossaster* from *Solaster*. Even here the divergence is not nearly so great as indicated by such extremes as *papposus* and *endeca*. Intermediate species with skeleton of *Crossaster* and the paxillæ of *Solaster*, as well as the two types of skeleton in such obviously close relatives as *papposus* and *squamatus*, baffle any attempt to make two generic groups. Whether it is convenient to retain *Crossaster* as a subgenus depends upon the importance attached to such a group. It would seem that the same objections apply here also.

Japanese specimens.—Pl. 95, figs. 1 and 2; pl. 113, fig. 4. In Japanese waters there is a representative species in general appearance resembling *papposus*, but differing in several important details. So far as the limited number of specimens allows one to judge, these differences are constant. *Solaster japonicus,* new species, differs from *Solaster papposus* in having more numerous and less prominent marginal plates, and seven to nine furrow spinelets (four in North Pacific *papposus*). Rays ten, rarely nine. A large specimen (R = 80 mm., r = 40 mm., R = 2 r) has twenty-six to twenty-eight marginals, while *papposus* of the same size have eighteen to twenty. Typically these marginals are separated by less than their own width, form a very regular series, their spinelets being very numerous, the peripheral quite short, and the rest graduated toward the center ones, which are decidedly shorter than the subambulacral spines. In some specimens the marginals are decidedly compressed and the longest spines near the ventral side of the paxilla. The adambulacral furrow spinelets are shorter than the actinals, less heavy, and in a regular comb, the middle members the longest. The spinelets are joined by a web nearly to the tip, the edges of the web forming around the end of each spinelet a flattened pad or flap. This web is joined by the transverse web of the actinal comb, a peculiarity not observed in North Pacific *papposus.* As a result the furrow and actinal series of adambulacral spines are more or less closely joined. In the actinal series are seven to nine tapering spinules (six in small specimens), longer and stouter than the furrow spinelets, webbed for about half their length, the web continued as a flange of tissue over the pointed tip of each spine. Mouth plates with twelve to fourteen webbed marginal spinelets, the inner two or three abruptly the largest; suboral spinules four to nine webbed, but not connected with the marginal series. They are variable in length, though longer than the shorter marginals. Actinal interradial areas paved with numerous small, four to eight spined paxillæ, which do not extend far along ray. Abactinal skeleton open meshed as in *papposus,* the paxillæ being of the same general type. Paxillæ numerous with long central and short peripheral spinelets (apparently deep-water examples have longer spinelets). No well-defined midradial series larger than the rest. (See pl. 95, figs. 1 and 2.) Eighteen specimens of this species have been examined from the following localities: Station 4818 (*type-locality*), off Sado Island, Sea of Japan, 225–245 fathoms, fine brown mud, eleven specimens; 4859, off Matsushima, Sea of Japan, 93 fathoms, green mud, one specimen: 4860; same locality, 122 fathoms, green mud, one specimen; 4867, Sea of Japan (36° 31′ N.; 129° 46′ E.), 150 fathoms, green mud, four specimens; 4871, Sea of Japan (36° 29′ 30″ N.; 129° 43′ 30″ E.), 60 fathoms, one specimen.

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[a] See Grieg, 1906, pl. 1, figs. 4 and 5, and text, fig. 7 (1-3).

Type.—Cat. No. 27788, U.S.N.M.

Genus HETEROZONIAS Fisher.

Heterozonias FISHER, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 172. Type, *Crossaster alternatus* Fisher.

Diagnosis.—Solasteridæ with a wide-meshed abactinal skeleton, and small pseudopaxillæ like *Solaster,* but differing from that genus in having a complete series of actinal intermediate plates to tip of ray and in the arrangement of marginal paxillæ, which consist of transversely oriented prominent inferomarginals alternating with longitudinally oriented less prominent superomarginals, all in a single linear series. Adambulacral armature as in *Solaster.* Papulæ numerous and prominent.

HETEROZONIAS ALTERNATUS (Fisher).

Pl. 96, figs. 1-3; pl. 112, figs. 5, 5*a-b*.

Crossaster alternatus Fisher, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 131.

Diagnosis.—Rays ten. R = 2.6 to 2.9 r. Breadth of ray at base, ½ r. General form flattened; abactinal surface of disk slightly convex, capable of inflation, but flattened on central part; abactinal surface of rays slightly rounded; margins well rounded; actinal surface nearly flat; interbrachial angles rather acute; abactinal skeleton open reticulate, the ossicles slenderer than in *S. papposus;* papulæ large; paxillæ small, well spaced; marginal plates of two kinds in a single series; more prominently spinous transversely placed paxilliform plates alternating with usually two longitudinally oriented plates with very short spinelets; marginal plates actinal in position on basal half of ray; actinal interradial areas small, with few plates set fairly close together; a single series of very small intermediate plates extending to end of ray; adambulacral plates with four to eight furrow spinelets and a transverse series of four actinal spinules.

Description.—Abactinal integument rather thin but tough and pliable, parchment-like, quite opaque, and obscuring the ossicles unless dried. Skeleton open and forming a network with fairly wide meshes, which are irregular and largest on disk; connecting ossicles slender, often irregular; inclosed within meshes, small free irregular ossicles; these often absent, but usually present on disk and most numerous near its center. Paxillæ with a two to four slender-lobed base and a low stout pedicel surmounted by usually four to six, or far along ray two or three, and on disk sometimes as many as nine, rough, delicate tapering, pointed, spinelets inclosed in a delicate membranous sac, which fits tightly about each spinule for about half its length, leaving only its basal part obscured. In consequence of the open character of skeleton, the paxillæ are well spaced, but are very much smaller and more numerous than in *S. papposus.* They are largest and most widely spaced on radial areas midway between center of disk and margin, thence rapidly diminish in size toward extremity of ray and less toward center of disk. The paxillæ are not arranged in very evident series, although along the lateral regions of the rays an arrangement in quincunx is observable, though not so well marked as in *S. borealis* or *paxillatus.* A bare sulcus leads from each interradial angle halfway to center of disk. These bare areas are about 1 mm. wide and are paved solidly with ossicles, which are the upper edge of the incomplete calcareous interbrachial partition. At the inner end of this bare area, in one interradius, is the madreporic body surrounded by several paxillæ; in the other radii several slightly larger paxillæ hold a similar position. Papulæ large, partially obscuring the small paxillæ; absent from bare interradial areas; two to seven or eight to each mesh of skeleton on rays and as many as fifteen on disk, or even more where meshes are incomplete. Papulæ commonly 3 mm. long, pointed. In the interradii a number of the abactinal plates are actinal in position, because the marginal plates are drawn inward toward the mouth. Thus in the type the distance between marginal plates and interradial angle is 6 to 8 mm. Consequently the dorsal integument with plates and papulæ is drawn upon actinal surface.

Marginal plates conspicuous; about fourteen to twenty prominent, compressed, rather widely spaced, transversely oriented, paxilliform plates represent the inferomarginal series, and between any two of these in the same linear series are one to three, usually two, longitudinally oriented, much lower and slightly smaller plates representing the superomarginal series, although now forming a single series with inferomarginals. The prominent marginals become more conspicuous toward tip of ray, acquiring a heavy, compressed pedicel often higher than its width at top and very paxilliform in appearance, bearing two transverse rows of about eight to sixteen tapering needle-like spines one and a half to twice as long as the pedicel, which increase in length but decrease in number toward extremity of ray. Beyond proximal fourth of ray there are two well-defined series of these spines, of which the adoral are the shorter, and in the other series about three skin-covered spines become much larger than the rest and have very sharp points. Distally the spines form two palmate series, but there is more or less variation in their numbers. The nonprominent longitudinally oriented plates vary considerably in size and decrease markedly in size distad, whereas the others become more prominent. Except at base of ray they are not nearly so high as transverse plates and are rounded to elliptical-oblong, bearing upward to twenty-five very short spinelets in about three or four longitudinal series. At tip of ray these plates are very small, bearing a group of five or more delicate spinelets.

Actinal interradial areas small, with small, closely placed, paxilliform plates bearing four to ten spinelets, which are more delicate than those of abactinal paxillæ, although the latter are of about the same size. Interradial paxillæ about ten to twenty in number. Proceeding along ray almost to its tip is an inconspicuous series of very small actinal intermediate plates, often rather widely separated, a plate usually opposite each adambulacral plate, and distally bearing only a single small spinelet, or none at all, proximally with two to five spinelets.

Adambulacral plates with a palmate furrow series proximally of six to eight, distally of four or five, very delicate, tapering sharp skin-covered spinules united for about a third their length by a web. Mesial spinules longest (about one-third width of plate in length), thence decreasing in length toward either end of series. On actinal surface of plate is a transverse comb of four or five slender, needle-like sharp spines, the two or three mesial the longest, the inner usually slightly longer than furrow spinules though often nearly twice as long; outermost spine usually nearly equal to the longest, which exceeds in length width of plate. These spines, like those of furrow series, are invested in membrane, which forms vane-like lateral expansions (causing the spinule to appear broad and flat near base) and unites them in a common web by their bases. On distal part of ray the large adambulacral spines are similar in size and appearance to the larger inferomarginal spines already described.

Mouth plates of the usual shape, rather prominent actinally. Each plate has three long slightly-tapering pointed spines at inner end, these decreasing in size outward, so that third spine is about one-half length of innermost; thence the series is continued to end of plate in seven or eight much shorter spines resembling those of first adambulacral plate. All spines are skin-covered and united basally by a web. On actinal surface, parallel with median suture and slightly nearer it than free margin, is a comb of two to eight skin-covered sometimes basally webbed spines similar to but smaller than corresponding series of first inferomarginal.

Madreporic body situated about midway between center of disk and margin, irregularly circular or oval, convex, irregularly and centrifugally striated; about 3 mm. in diameter.

Color in life, "salmon pink."

Young.—Young specimens agree very well with the large examples, except that the papulæ are less numerous, and there is a slight reduction in number of spines of interradial, marginal, and adambulacral plates, as well as fewer interradial and marginal plates. In small specimens there is more often only one superomarginal plate interpolated between the transversely oriented inferomarginals, and the former are slightly more superior in position, at base of ray, than in adults. Adambulacrals commonly with three to five furrow spinules proximally and three or four actinal. Usually only one or two large papulæ to a mesh. Abactinal spinelets are not fewer in number than in adults, except in very young specimens, but the suboral spines are often lacking. The marginal plates are very nearly on the margin in the interbrachial arcs.

Type.—Cat. No. 21932, U.S.N.M.

Type-locality.—*Albatross* station 2839, Santa Barbara Islands, California, in 414 fathoms on gray sand.

Distribution. From Washington to San Diego, California, in 316 to 603 fathoms.

Specimens examined.—Eighty-three, from the following stations:

Specimens of Heterozonias alternatus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2839......	Santa Barbara Islands, California....	414	gray sand...	32	U. S. Nat. Mus.
2936......	Off San Diego, California............	359	mud........	2	Do.
2937......	.....do............................	464	green mud...	3	Do.
2980......	Off Anacapa Island, California......	603	.....do......	2	Do.
3073......	Off Sea Lion Rock, Washington	477	.....do......	20	Do.
3188......	South of Monterey Bay, California.....	316	.....do......	2	Do.
3343......	Off Destruction Island, Washington.	516	.....do........	6	Do.
4307......	Vicinity of San Diego, California......	490–496	green mud, fine sand ..	7	*Albatross* 1904.
4317	.....do............................	471–510	.....do......	5	Do.
4400......	Between San Diego and San Clemente, Islands.	500–507	green mud....	3	Do.
4427......	Off Santa Cruz Islands, California ..	447–510	black mud..	1	Do.

Remarks.—This is one of the best-marked Solasteridæ of the North Pacific, the remarkable arrangement of the marginal plates making it easily distinguishable from any described form.

Genus LOPHASTER Verrill.

Lophaster Verrill, Amer. Journ. Sci. and Arts, ser. 3, vol. 16, 1878, p. 214. Type, *Solaster furcifer* Düben and Koren.

Sarkaster Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, July, 1905, p. 185. Type *Sarkaster validus* Ludwig.

Diagnosis.—Five-rayed Solasteridæ with cruciform or lobed abactinal paxilliform plates (without intermediate connecting ossicles) forming a quadrate or polygonal meshed skeleton; with two well-developed series of marginal paxillæ, and with usually a single series of spaced actinal intermediate plates extending far along ray, with or without a paxilliform tuft of spinelets; adambulacral plates with a furrow comb usually webbed, and with an actinal comb of spines, often oblique, behind the furrow series.

Remarks.—Much may be said for merging this genus with *Solaster*. The type is, I believe, more distinct than *Crossaster*, and is kept separate for convenience, and in the belief that, although close to *Solaster*, intergrading species have not been demonstrated.

A curious misapprehension has for some reason grown up around this genus. Sladen states in his key that there are no actinal intermediate plates along the ray, and Hamann in Bronn's Thierreich follows Sladen. A specimen of *L. furcifer* from the Kara Sea, which I have, has a single series of spaced actinal intermediate paxillæ placed alternately with the inferomarginals, extending very nearly to the tip of the ray (to within 6 mm., R being 45 mm.). Specimens of *L. furcilliger vexator* described below are similarly provided, although in some specimens they are suppressed except for widely-spaced plates on the outer part of the ray. *L. furcilliger vexator* is an undoubted *Lophaster*, and is believed to intergrade with *furcilliger* in deeper water; with the latter *Sarkaster validus* is either identical or closely related. It follows, therefore, that *Sarkaster* can not be maintained, for its alleged distinguishing character is shared by *Lophaster*. Even if in *Lophaster furcifer* intermediate plates are not always present on the ray, the case against *Sarkaster* is not altered.

LOPHASTER FURCILLIGER Fisher.

Pl. 79, figs. 1, 2; pl. 114, figs. 1, 1*a*—*g*; pl. 116, fig. 5.

Lophaster furcilliger Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 312.

Diagnosis.—Rays five. R = 70 mm., r = 16 mm., R = 4.38 r. Breadth of ray at base 18 mm. or a little less than one-fourth R. Disk rather small, rays long, tapering from narrow base very gradually to pointed extremity, ambulacral furrow wide and shallow; tube feet with small sucking disk. As compared with *L. furcifer*, rays narrower and longer, abactinal skeleton more open, paxillæ much slenderer, higher, with longer and more delicate spinelets having only two or three, less often four sharp points; marginal paxillæ higher, more spaced, actinal interradial areas much smaller with fewer plates, which with the intermediate plates along ray have more delicate spinelets; adambulacral spinelets longer and more delicate, and the series as wide apart as length of a series, not close together.

Description.—Abactinal surface beset with well-spaced paxillæ, which have rather long (2 to 3 mm.) slender pedicels, with a capitate summit beset with two glomerular tufts of numerous (twenty or even more) long, delicate, glassy spiculiform spinelets, flattened, flaring, and with two or three, rarely four, delicate rather long teeth at the tip, these spinelets about 1 to 1.2 mm. in length and radiating in all directions; paxillæ largest on disk, decreasing in size toward end of ray. Papulæ two or three to a mesh of the skeleton in small specimens, gradually increasing with the size of the individual to about six or eight in type. There are more on disk than on the rays. Abactinal plates with four lobes on the lateral portions of the area and with two, three, four, or even five on the midradial region, where the meshes are irregular, five- or four-sided, and larger than the lateral quadrate meshes. All the meshes are much larger than in *furcifer*.

Marginal paxillæ forming two conspicuous series alongside of ray; they are well spaced and the superomarginals stand above the inferomarginals—that is, do not alternate. Superomarginal paxillæ much larger than the adjacent abactinal, and with stouter and longer pedicels (3.5 mm., type), and the spinelets have a number of sharp teeth scattered along the outer part (Pl. 114, fig. 1*f*); sometimes they are trifurcate. Inferomarginal paxillæ similar to the superomarginal, but sometimes a trifle more robust; about twenty-three to twenty-five to a ray in type.

Adambulacral plates short and broad, with wide intervals between successive plates, the suture being wider than the length of exposed surface of plate; furrow series consisting of four spinelets at base of ray, which are soon reduced to three, then to two beyond middle of ray, and finally to one; these spinelets rather long, delicate, skin-covered and united for a third or a half their length by a web; when there are four, they are graduated in length toward the adoral, which is shortest; when there are three, the middle is usually longest, and commonly the adoral when there are two; the separate series well spaced from one another and the spinelets as long as or even longer than width of the plate. On the actinal surface is a series of four, three, or two longer and more robust, tapering, pointed spinelets, disposed in an oblique transverse series, and decreasing in length as they recede from the furrow, skin-covered, often having lateral expansions, and the bases united by membrane; when there are three or four spines the outer is usually much shorter than the rest. Northern specimens, as, for example, from station 3075, have the spinelets much more heavily enveloped with membrane.

Mouth plates fairly large, spade-shaped, and prominent actinally; median suture wide, roofed with membrane; furrow spinelets seven or eight, long, skin-covered, united for about a third to a half their length by a web, increasing very slightly in length toward the innermost, which is rather more robust than the others. Near the middle of the suture margin are one to four much slenderer spinelets, which are shorter than those on furrow. They are webbed basally. The type has only one or two spines; apparently the specimens from very great depths have the fewest and slenderest suborals.

Actinal interradial areas much reduced and with few spine-bearing plates in each interradius. The type has about eight or nine low paxillæ within the area determined by the first marginal paxillæ. An extreme specimen from station 4237 not typical has about twenty-four plates, including the area to the limit of two rows of plates on each ray. These paxillæ have low pedicels and spinelets somewhat longer ending in several points. A single series extends from the third inferomarginal nearly to tip of ray, decreasing in size distally. These paxillæ usually stand in the interval between two inferomarginals and are therefore widely separated. Near the base of ray, however, the plates are closer and there may also be one opposite the inferomarginal, although sometimes it lacks a paxillar development. In the interradial region the plates touch one another.

Madreporic body convex, situated about midway between center and margin.

Color in life, salmon pink, tip of arms yellowish white.

Variations.—The following table shows variations in proportions of Californian examples:

Station.	R.	r.	R: r.	Breadth of ray at base.
Type	70	16	4.38: 1	[a] 18.0
4425	32	8	4: 1	9.5
4425*a*	30	7	4.2: 1	9.0
4407	35	7	5: 1	7.0
	29	7	4.1: 1	9.0

The following are similar measurements of *L. furcifer:*

Locality.	R.	r.	R: r.	Breadth of ray at base.
2471 [b]	36	13	2.8: 1	[a] 16
Figure [c]	53	20	2.65: 1	21–25
Kara Sea	45	17	2.7: 1	19

[a] Compare with length of ray, which will give an idea of robustness of ray.

[b] Off Nova Scotia, 218 fathoms.

[c] Measurements from figure, Danielssen and Koren, Asteroidea: Norwegian North Atlantic Expedition, 1884, pl. 8, fig. 12.

The Alaskan examples are not quite typical, tending slightly toward *vexator* in having less widely spaced adambulacrals, slightly compressed inferomarginal paxillæ and not quite so high or so delicate paxillæ. Some examples recorded under *vexator* from station 3331 stand nearly midway between the extremes, though nearer *vexator* in the structure of abactinal and marginal paxillæ, and spinelets. Possibly the intermediate depths at which these were taken may in a measure account for the less extreme development of the characters which make *furcilliger.*

The type from deep water has the distinctive characters of the species most pronounced; the long rays, long paxillæ pedicels and their crown of delicate glassy furcate spiculiform spinelets usually radiating to form beautiful tufts resembling miniature composite flowers; very prominent marginal paxillæ, small actinal interradial areas with few plates, and long delicate furrow spinelets.

Type.—Cat. No. 22341, U.S.N.M.

Type-locality.—*Albatross* station 4425, between Santa Barbara and San Nicholas islands, 1,084 to 1,100 fathoms, green mud, sand, globigerina.

Distribution.—From south of the Alaska Peninsula to southern California, thence south to the Galapagos Islands, 192 to 1,100 fathoms.

Specimens examined.—Twenty-four, from the following localities:

Specimens of Lophaster furcilliger examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2860	Off Queen Charlotte Island, B. C.	876	green mud	16	U. S. Nat. Mus.
3075	Off Sea Lion Rock, Washington	859	do	1	Do.
3338	South of Unga Island, Alaskan Peninsula.	625	green mud, sand	1	Do.
4237	Vicinity of Yes Bay, Behm Canal, Alaska.	192	green mud	1	*Albatross*, 1903.
4407	Vicinity of Santa Catalina Island, California.	334–600	rocks, shells, fine gray sand	1	*Albatross*, 1904.
4425	Between Santa Barbara and San Nicholas Islands, California.	1,084–1,100	green mud, sand, globigerina	3	Do.
No label				1	Do.

Remarks.—This species, although very well marked in great depths, seems gradually to change in shallower water to *L. furcilliger vexator*. However, an example referable to *furcilliger* rather than to *vexator* was taken in 192 fathoms off southeast Alaska. The specimens of *vexator* from 350 fathoms north of Unalaska are not typical, but are nearer *vexator* than to the present form. The specimens of *furcilliger* from stations 2860 and 3075 are not typical, but vary slightly in the direction of *vexator*. It is probable that there is a slight change northward in addition to the change caused, it would seem, by shallow water. Specimens of *vexator* from shallow water show the characteristics of the race more prominently than do those from deeper than 200 fathoms.

Venturing somewhat upon the speculative, one may suggest that *vexator* varies with latitude as well as with depth, and that ranging into deep water it gradually becomes the form known as *furcilliger*, which assumes its extreme characters only at great depths (as the type-locality). If northern *furcilliger* is derived from northern *vexator*, and southern *furcilliger* from the southern *vexator*, specimens of *furcilliger* from the two extremes would naturally show some differences even if the remoteness geographically did not also exert an influence, which it probably does. It is likely that *furcilliger* pushes farther south at great depths than its possible originator does at shallower. Also, once established *furcilliger* may return to shallower water where bottom and temperature are favorable; at least specimens nearer the type than to any other form are found in less than 200 fathoms. It hardly seems possible that these are individual variants of *vexator*.

L. vexator is much nearer to *furcifer* than is *furcilliger*. This seems very suggestive. If intergradation occurs between *furcifer* and *vexator* and *vexator* intergrades with *furcilliger*, as seems demonstrable, then logically, *Sarkaster validus* (scarcely if at all specifically separable from *furcilliger*) would be connected by a complete series with *L. furcifer*, and would naturally become, along with *furcilliger*, a subspecies of *furcifer*. The intergradation of *furcifer* and *vexator* is, however, yet to be demonstrated, but there is no doubt that *Sarkaster* is only an extreme of *Lophaster*.

Sarkaster validus Ludwig[a] ranges from the Galapagos to the Tres Marias Islands and from 680 to 286 fathoms. There are no important differences between this species and the variable *Lophaster furcilliger.* The type of *furcilliger* happens to be from deeper water than *validus,* and has more delicate paxillæ and spines generally. The Alaskan examples of *furcilliger* from lesser depths are nearer *validus,* having the inferomarginals larger than the superomarginals, lower paxillæ, and stouter rays. Although Ludwig's excellent description and figures seem to indicate slight differences, these are more than compensated by the variations of the specimens at my disposal. The Alaskan specimens of *furcilliger* are quite as distinct as is *validus* but if one started to name the intergrading forms with *vexator* there would be no end.

LOPHASTER FURCILLIGER VEXATOR Fisher.

Pl. 80, figs. 1, 2; pl. 114, figs. 2, 2*a*.

Lophaster furcilliger vexator Fisher, Zool. Anz., vol. 35, March 29, 1910, p. 574.

Diagnosis.—Similar to *L. furcilliger,* but with larger disk, thicker rays, much stouter paxillæ both abactinal and marginal, and with stouter abactinal spinelets having six to ten points instead of two to four, heavier adambulacral spines, and more closely placed adambulacral plates. Perhaps intermediate between *L. furcifer* and *L. furcilliger.* Type, R = 89 mm.; r = 27 mm.; R = 3.3 r. Breadth of ray at base, 30 mm., or about one-third R.

Description.—This form, variety, race, or small species stands near to *furcilliger* although the extremes are decidedly different in appearance. *Vexator* is a much stouter animal with thicker rays, more robust paxillæ, and stouter skeletal parts, due possibly to the shallower habitat. In *furcilliger* the pedicels of paxillæ are decidedly slender and the spinelets are about a half to two-thirds the extreme length of pedicel. The spinelets are very delicate and glassy with two or three extremely sharp points at the flaring tip (sometimes four), and commonly one or two series of perforations along the middle of the spinelet. But in typical *vexator* the pedicels are shorter and stouter, and the spinelets are about the same length as in *furcilliger* or shorter, ending in six to ten points distributed along the outer third or half of the spinelet. There are also several rows of perforations along the center of spinelet where the wing-like expansions or buttresses which terminate in points join to form the core of the spinelet. The abactinal plates or bases of paxillæ are of the same general structure as in *furcilliger,* but usually stouter. Papulæ in type and large examples ten to twenty-five to an area on disk and midradial region, laterally five or six. Proximally they sometimes encroach upon the marginals and lie intra-marginally, but this is not usual and occurs only in very large specimens such as the type.

Marginal plates very robust, the inferomarginal paxillæ stouter than superomarginal and compressed toward the end in large examples. The difference in size between the marginal paxillæ in typical *furcilliger* is slight or not marked and the inferomarginals are not compressed at the tip. The marginal spinelets are variable in length, but usually shorter, stouter, and more dentate than in *furcilliger.*

Adambulacral plates with the furrow combs typically nearer together than in *furcilliger,* but some specimens having them slightly spaced and hence intermediate (station 3331). Armature of four or three furrow spines, but specimens from station 3331 with three, two, and finally one as in *furcilliger*, and the series are slightly spaced also, as noted above. The subambulacral spines agree very nearly in number with the furrow, to which they are subequal in length, but are considerably longer and thicker in a large (and not in a small) specimen from station 3331. The armature differs from that of *furcilliger* mainly in having stouter spines, narrower spaces between consecutive series, and heavier membrane on the spines.

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[a] 1905, p. 185, pl. 15, figs. 75, 76; pl. 29, figs. 171–173; pl. 30, figs. 174–177.

Mouth plates differ from those of *furcilliger* in having slightly stouter furrow spines and more numerous actinal or suboral spines, there being in the type three to six about as long as the furrow spines. In *furcilliger* (typical) only one or two spines are present, although a northern example, which is not typical in some other respects, has three suboral spines.

Actinal intermediate plates about as numerous as in *furcilliger*. In a specimen from station 3330 the paxillæ along the ray are very inconspicuous, but in another example also large, they are fairly large, fully as large as in typical *furcilliger*. A specimen station 3331 lacks actinal intermediate paxillæ on the rays, although here and there far along ray a small one may be seen.

Type.—Cat. No. 27789, U.S.N.M.

Type-locality.—*Albatross* station 3350, off Point Arena, northern California, 75 fathoms, fine sand, mud; two specimens.

Distribution.—Southern Bering Sea to northern California in 75 to 350 fathoms, typically in less than 200, intergrading evidently in deeper water with the following form. Probably westward to Spitzbergen.

Specimens examined.—Fourteen, all from the National Museum collection, as follows:

Station 3330, north of Unalaska, 351 fathoms, black sand, mud, four; station 3331, same locality, 350 fathoms, mud, four; station 3339, east of Shumagin Islands, 138 fathoms, mud, gravel, two; station 3350, type-locality, two; no locality, two.

Remarks.—This form may ultimately be found to intergrade with *L. furcifer* of the Arctic Ocean and of the North Atlantic. *Vexator* differs from typical *furcifer* in having a more open abactinal skeleton with consequently more widely spaced paxillæ, higher paxillæ with longer spinelets, much smaller actinal paxillæ (about as in *furcilliger*) and longer adambulacral spines. If equal sized specimens of the two forms are compared, *L. furcifer* is seen to have wide rounded interbrachial arcs which merge gradually into the ray. *Vexator* has a smaller disk, never rounded interbrachial arcs, but acute angles, the rays being sometimes swollen at base so that the marginal and adjacent abactinal paxillæ of two rays interlock. *L. furcifer* reminds one of a five-rayed *Solaster*, whereas *L. vexator* suggests a five-rayed "*Crossaster*."

Grieg[a] has furnished notes on the variation of *L. furcifer* from which it would appear that a form resembling *vexator* occurs off Spitzbergen.[b] This can not be confused with true *furcifer* as the rays have an entirely different shape, and the paxillæ are more spaced. It is not possible to determine whether this form figured by Grieg is a separate species or only a variation of *furcifer*. At any rate it must be considered separately from *furcifer*, and if the same as the race inhabiting Bering Sea and the depths off northwestern North America, should be designated as distinct from *furcifer*, the typical form of which appears not to be found in this area.

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[a] See Report of the Second Norwegian Arctic Expedition in the *Fram*, 1898–1902, Echinodermata, 1907, 8 (pl. 1, figs. 3 to 5; pl. 3, fig. 1). Echinodermen von dem norwegischen Fischereidampfer *Michael Sars* in den Jahren 1900 to 1903 gesammelt, III, Asteroidea, Bergens Museums Aarbog, 1906, No. 13, p. 69, text fig. 9, and pl. 2, figs. 6–9.

[b] Text fig. 9, Asteroidea, *Michael Sars* Expedition.

Vexator may be a species which invades the North Atlantic and which is quite distinct from the resident *furcifer*. We seem to have to do with at least two distinct forms which range together to the north of Scandinavia. Even if *vexator* is only a variety or "forma" of *furcifer*, conditions are such that it is the type which has survived in the North Pacific at lesser depths, and as it evidently intergrades with *furcilliger* its name has been linked with that species rather than with *furcifer*, with which intergradation is not demonstrated.

Family KORETHRASTERIDÆ Danielssen and Koren, 1884.

Korethrasteridæ Danielssen and Koren, 1884; Bell, 1892; Gregory, 1900; Fisher, 1905.
Korethrasterinæ Sladen, 1889; Perrier, 1904.

Spinulosa resembling superficially the Solasteridæ, but lacking actinal intermediate plates, and with the armature of the adambulacral plates forming with that of the inferomarginals a single transverse series, never webbed; inferomarginals never paxilliform; interbrachial septa partly calcified; abactinal skeleton composed of roundish plates, or lobed plates forming a wide mesh, bearing a tuft of spinelets either independent or united by web; mouth plates plowshare-shaped, resembling those of the Pterasteridæ.

Remarks.—This small family is usually placed under the Solasteridæ which it resembles in respect to the abactinal skeleton and spinulation, but differs in lacking actinal intermediate plates and in having the mouth plates of the *Pteraster* type, not the *Solaster* form. The armature of the adambulacral plates is also different, being nearer that of the Pterasteridæ, though entirely lacking a web. The inferomarginals are never paxilliform as in the Solasteridæ and Pterasteridæ.

The Korethrasteridæ seem to stand naturally between the Solasteridæ and Pterasteridæ, combining a few of the characteristics of each family. The Solasteridæ are more homogeneous if *Peribolaster* and *Korethraster* are removed, for the main likeness is to be found only in the abactinal skeleton. The reticulate structure such as is found in *Peribolaster* and that of independent plates as in *Korethraster* is paralleled in the Solasteridæ, where the principal genera have a reticulate skeleton, but *Lætmaster* (olim *Ctenaster*) is more comparable to *Korethraster*, having the abactinal platelets not united by intermediate ossicles or by their own processes.

The structure of the actinal skeleton is more homogeneous, however, and is distinctly nearer that of the Pterasteridæ than of the Solasteridæ, for the mouth plates are of the characteristic *Pteraster* form and the actinal intermediate plates of the Solasteridæ are lacking. The inferomarginals are never paxilliform but bear a prominent spine (or two spines) and are therefore different from those of the Pterasteridæ. The adambulacral armature is more like that of *Pteraster* than of *Solaster*.

KEY TO THE KNOWN GENERA OF KORETHRASTERIDÆ.

Abactinal plates polygonal or roundish in outline, the spines composing the paxilliform tufts naked and free.. ....*Korethraster* Thompson.
Abactinal plates cruciform forming wide meshes; the spines composing the paxilliform tufts in membranous sacs which are united together in the interior of the group.........*Peribolaster* Sladen.

Genus PERIBOLASTER Sladen.

Peribolaster Sladen, Narr. *Challenger* Exp., vol. 1, 1885, p. 616 (no type-species); *Challenger* Asteroidea, 1889, p. 464. Type, *P. folliculatus*.

Diagnosis.—Korethrasteridæ having the abactinal surface paved with cruciform plates whose delicate lobes are connected by supplementary ossicles forming a fairly regular network of large quadrangular meshes over the entire surface. On the center of each primary abactinal plate is borne on a small boss a fascicule of delicate, subequal spinelets, enveloped in membranous sheaths, united in the interior of the fascicule. One to several papulæ present in each mesh; no actinal papulæ. No actinal intermediate plates. Adambulacral armature forming with that of the inferomarginal plates a transverse series of four to six large single isolated spinelets invested with membranous sacs. Mouth plates fairly large, of the type of the Pterasteridæ, and with a prominent median keel, a few marginal and a single or no suboral spine. Tube feet in two or four rows, with fleshy buttonlike terminal disk. No pedicellariæ.

PERIBOLASTER BISERIALIS Fisher.

Pl. 97, figs. 1, 2; pl. 114, figs. 3, 3*a–c;* pl. 115, fig. 5.

Peribolaster biserialis Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 313.

Diagnosis.—Differing from *P. folliculatus* Sladen in having the tube-feet in two series, in having a much larger disk and relatively shorter rays, a more open abactinal skeleton, with fewer and more widely spaced primary plates, and longer spinules; adambulacral plates with three and inferomarginals with a single spine, the four forming a single transverse series (six in *folliculatus*) no suboral spine as in *folliculatus*. R=25 mm.; r=10 mm.; R=2.5 r. (Type, R=20 mm.; r= 7.5 mm.; R=2.6 r; breadth of ray at base, 8.5 mm.) Abactinal surface convex, rather flexible; form stellate; rays rather short and robust, wider than high, tapering, the outer part somewhat slender and often recurved; interbrachial arcs acute, the rays being constricted slightly at the base; edges of ray rounded, due to inflation of abactinal integument; tube feet strictly biserial.

Description.—Abactinal plates ordinarily obscured by the skin unless dried. These plates are usually four- (sometimes three-) lobed, the lobes being connected by rod-like intermediate ossicles typically longer than the lobes themselves, forming a very open reticulate skeleton with wide interspaces for the papulæ. No serial arrangement of plates is very apparent but they are nevertheless in fairly regular order, there being in the largest example about five longitudinal series of plates. The plates of adjacent rows alternate and the papular areas are quadrate. Each plate has a slight eminence or tabulum surmounted by a brush-like fascicule of three to five delicate, glassy, sharp spinules about 3 mm. long, which are united into a compact group by a membrane, the spinules sometimes radiating a trifle; spinules decreasing in length toward tip of ray, but increasing slightly toward margin. Papulæ long and conspicuous, three to seven to an area. The spinules give a bristling appearance to the abactinal surface, and the membrane connecting the spinules is frequently emarginated at their tips. The groups appear distinctly spaced owing to the large meshes of the dorsal skeleton. Anal aperture surrounded by a row of short obtuse spinelets, and to one side of it the flat subcircular central plate may be seen in a dried specimen.

Actinal surface paved with two longitudinal rows of band-like plates, which are comparatively wide and short: (1) the adambulacrals bordering the furrow, and (2) external to them a series of equally regular plates, probably the inferomarginals. Adambulacrals much wider than long and separated by prominent sutures; each plate with a transverse series of three prominent spinules, sheathed individually in membrane, which extends beyond the tip in a short sacculus; each spinule surmounting a slight boss on the plate, one situated on the furrow margin, another on the extreme other margin, and one exactly midway between the two; inner spinule 2 mm. long, and the other two successively slightly longer and stouter.

Inferomarginal plates a trifle longer than adambulacrals and not quite so wide, so that they do not exactly correspond to the latter, even though the sutures are not so prominent. Surface of each plate actinal in position and slightly convex, and the outer, lateral end bearing a prominent membrane-invested spinule, 3 to 3.5 mm. long, which superficially appears to stand in a linear series with the adambulacral armature; inferomarginal spinules, of which about thirty-five can be counted to the side of each ray, decreasing in size toward extremity, where both marginal and adambulacral plates with their armature are very small; about ten lateral cruciform plates immediately adjacent to (above) inferomarginals, form perhaps the superomarginal series.

Mouth plates very prominent actinally, the exposed surface rising toward the median suture; the combined pair thus with a very prominent but rounded beak about midway between inner and outer angles, or a little nearer the outer; margin of each plate rounded, but somewhat angular where the furrow edge merges with that turned toward the mouth; general form of mouth plates strongly recalling that of *Pteraster* and allied genera, the median beak on the actinostomial margin, in line of the median suture, being present; armature consisting of four marginal spinules, that nearest the mesial beak being largest, the third situated on angle between furrow and actinostomial margin at a lower level in the furrow than the other spinules, and often directed across or down into the furrow, while the others are reflexed; fourth spine commonly standing somewhat on actinal surface; all enveloped in membrane, which is prolonged beyond the tip in a sacculus.

Actinal interradial areas very small; apparently no actinal intermediate plates.

Madreporic body of medium size, situated about midway between center of disk and margin, irregularly circular in outline, with coarse, often branching, centrifugal ridges and narrower striations; anal opening somewhat eccentric, surrounded by low, cylindrical, granuliform spinelets; ambulacral furrows wide; actinostome not very wide, often completely closed over by mouth plates; tube feet in two series and with a button-like terminal disk.

Anatomical notes.—Stomach large and eversible, the hepatic cœca being large and extending to end of ray. Intestinal cœcum of medium size, saccular, depressed, slightly subdivided on the periphery into a few irregular broad lobes. Gonads on either side of the interradial septum and opening on the side of the ray close to interradial line. Septa partly calcified. Ampullæ double. Tube feet without calcareous deposits.

Type.—Cat. No. 22342, U.S.N.M.

Type-locality.—*Albatross* station 4410, between Santa Catalina and Santa Barbara Islands, California, 178 to 195 fathoms, fine gray sand and rocks.

Distribution.—Southern Bering Sea and off southern California, in 57 to 313 fathoms.

Specimens examined.—Forty-six, from the following stations:

Specimens of Peribolaster biserialis examined.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms.			
2927	Off San Diego, California	313	green mud	1	U.S.Nat.Mus.
3317	North of Unalaska	165	coarse sand, gravel, rocks	1	Do.
4399	Between San Diego and San Clemente Island.	264–285	fine gray sand.	2	*Albatross*, 1904.
4410	Between Santa Catalina and Santa Barbara Islands.	178–195	gray sand, gravel	2	Do.
4421	Between Santa Barbara and San Nicholas Islands.	291–298	gray mud, rocks	7	Do.
4788	Off Medni, Commander Islands	57	green sand	3	*Albatross*, 1906.
4790	Off Bering Island	64	pebbles	3	Do.
4791	do	76	rocky	17	Do.
4792	do	72	pebbles	10	Do.

Remarks.—One other species of this genus is known, *P. folliculatus* Sladen, from 45 fathoms off Chile (46° 53′ S.; 75° 12′ W.). The more striking differences between the two forms are the arrangement of the tube feet in two series in *biserialis* (four in *folliculatus*), its more open abactinal skeleton, fewer plates, longer paxillar spinules, and less numerous actinal spines (four instead of six in each transverse row). A prominent furrow spinelet is present in *biserialis*, the mouth plates have four marginal and no suboral spines, the inferomarginal plates may be easily distinguished from the adambulacral if dried, and the madreporic body, though variable in size is relatively smaller than in *folliculatus*. Judging by Sladen's figure the rays of *folliculatus* are longer and the fascicules of spinelets much more numerous and compactly placed than in *biserialis*.

In the arrangement of tube feet, *biserialis* is not precisely typical of the genus, but in other characters the two known species are essentially similar.

Family PTERASTERIDÆ Perrier, 1875.

Spinulosa with cruciform or lobed plates bearing paxilliform groups of spinelets which support a supradorsal canopy or membrane distinct from the abactinal wall; between the two a nidamental cavity is formed, opening centrally by a valved aperture, the osculum; actinolateral spines (arising from adambulacral plates) present supporting an actinal web, or merged in actinal floor; external to adambulacral plates, a series of segmental apertures all along ray, opening into nidamental cavity and guarded by a specialized opercular spinelet or papilla; no actinal intermediate plates; mouth plates broad and plowshare-shaped; membranous interradial septa.

KEY TO THE KNOWN GENERA OF PTERASTERIDÆ.

a^1. Armature of adambulacral plates forming transverse combs, the spinelets united by a web.
  b^1. Supradorsal membrane with muscular fibrous bands; actinolateral spines not completely merged in actinal floor, but the webbed tips forming a free independent ventro-lateral fringe.
    c^1. Muscular bands of supradorsal membrane not conspicuous; usually not regularly reticulated and circumscribing the spiracula, but meandering or crisscrossing, usually very inconspicuous; sometimes spicules are present in supradorsal membrane. *Pteraster*[a] Müller and Troschel, p. 344.
    c^2. Muscle bands conspicuous, regularly reticulated; no supradorsal spicules.
      d^1. Adambulacral plates of two kinds, less prominent alternating with more prominent, and correlated with them two sorts of furrow combs, one longer and set farther into furrow, the other set back slightly; actinolateral membrane broad and fleshy; tube feet in four rows...*Diplopteraster* Verrill, p. 370.
      d^2. Adambulacral plates not of two kinds; tube feet in two rows; actinolateral membrane narrow...*Retaster* Perrier.
  b^2. No muscular fibrous bands in supradorsal membrane; actinolateral spines merged in actinal floor; no lateral fringe.
    c^1. Paxillæ spinelets (15 to 30), long and hair-like, protruding freely through the membrane; adambulacral armature partly horizontal in disposition; one pair of suboral spines united by web to marginal mouth spines..*Marsipaster* Sladen.
    c^2. Paxillæ spinelets (five or six) short, robust, not protruding; adambulacral armature perpendicular in disposition; three pairs of suboral spines, free and independent..*Calyptraster* Sladen.
a^2. Armature of adambulacral plates not forming transverse webbed combs; spinelets free.
  b^1. Nidamental cavity spacious; supradorsal membrane well developed; spinelets of paxillæ supporting the membrane, not protruding through; muscle fibres of supradorsal membrane well developed; spiracula present.
    c^1. Mouth plates large with suboral spines; actinolateral spines long, projecting beyond border of ray...*Hymenaster* Thomson, p. 373.
    c^2. Mouth plates small, without suboral spines; actinolateral spines short not reaching to interradial line; supradorsal membrane regularly reticulated, each mesh containing a spiracle. *Cryptaster* Perrier.
  b^2. Nidamental cavity small, the spines projecting through the thin supradorsal membrane which lacks or has only very rudimentary muscle fibres..........................*Benthaster* Sladen.

Genus PTERASTER Müller and Troschel.

Pteraster MÜLLER and TROSCHEL, System der Asteriden, 1842, p. 128. Type, *Asterias militaris* O. F. Müller.

Hexaster PERRIER, Comptes rendus, vol. 112, No. 21, May 1, 1891, p. 1227; Mém. soc. zool. France, vol. 4, 1891, p. 267. Type, *Hexaster obscurus* Perrier.

Temnaster VERRILL (subgenus), Proc. U. S. Nat. Mus., vol. 17, 1894, p. 275; Amer. Jour. Sci. vol. 49, 1905, p. 202 (as genus). Type, *Pteraster* (*Temnaster*) *hexactis* Verrill=*Pteraster obscurus* (Perrier).

Pterasterides VERRILL, Amer. Naturalist, vol. 43, Sept., 1909, p. 547, footnote. Type, *Pteraster aporus* Ludwig.

Diagnosis.—Pterasteridæ having muscle-bands in the supradorsal membrane, but these as a rule not regularly reticulated; adambulacral armature in the form of transverse webbed combs; actinolateral spines forming a free independent lateral fringe, not merged in actinal floor; supradorsal membrane frequently with small spicules (but not invariably).

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[a] *Lophopteraster* Verrill (Amer. Journ. Sci., vol. 49, 1895, p. 202) is stated to differ from *Pteraster* "in having a very prominent, solid crest or keel-like prominence on the center of each jaw; it forms the inner angle of the jaw, separating the two groups of oral spines in the middle." Otherwise it is like *Pteraster*. Type, *Pteraster abyssorum* Verrill. This may be a good genus, but it seems rather slightly differentiated from *Pteraster*, the shape of the mouth plates constituting the only difference.

KEY TO THE SPECIES OF PTERASTER HEREIN DESCRIBED.[a]

- a^1. Rays constantly five.
  - b^1. Form stellate; R exceeding 1.8 r, usually 2 r or more.
    - c^1. Supradorsal membrane reticulated, very thin and delicate; spiracula six to ten to an area; oral spines two .... *gracilis*, p. 349.
    - c^2. Supradorsal membrane not reticulated.
      - d^1. Tube feet in two series; supradorsal membrane with spiny spicules; oral spines webbed; suboral stout.
        - e^1. R=2 to 2.5 r; adambulacral comb with more than five spines; oral spines six to eight; suboral spine cylindrical, not three edged; paxilla stalk low with three to five spines. *militaris*, p. 346.
        - e^2. R=1.87 r; adambulacral comb with five spines; oral spines five; suboral very large, three-edged; paxilla stalk high with six spines.............................. *trigonodon*, p. 348.
      - d^2. Tube feet crowded, in four series, at least proximally; supradorsal membrane either without deposits or with a very few simple rods; oral spines partly or wholly webbed; suboral slender.
        - e^1. R=2 r; adambulacral comb of three or four spines; oral spines four; no small lateral pockets back of aperture papillæ; no deposits in supradorsal membrane; paxilla spines usually two, longer; spiracula present .... *jordani*, p. 350.
        - e^2. R=1.8 to 2.5 r; adambulacral comb of five spines proximally; oral spines five; small shallow pockets just back of aperture papillæ; supradorsal membrane with few scattered simple rods; paxilla spines three, shorter; spiracula absent .... *marsippus*, p. 352.
  - b^2. Form more or less pentagonal, R less than 1.8 r.
    - c^1. Oral spines six, free, suboral spine very slender; spiracula very numerous; lateral fringe defining ambitus; no spicules in supradorsal membrane; R=1.4 r........... *coscinopeplus*, p. 354.
    - c^2. Oral spines five to seven, the entire ten to fourteen united by a continuous membrane.
      - d^1. Size large; membranes thick; supradorsal membrane more or less reticulated by muscle bands, or else creased by fine furrows into which open the spiracula; actinolateral membrane very narrow. R=1.44 to 1.8 r.
        - e^1. With well developed rays; reticulations usually evident at least on sides of body. R=1.6 to 1.8 r... *tesselatus*, p. 359.
        - e^2. More arcuately pentagonal in form. R=1.44 r; no evident reticulations; supradorsal membrane with many fine irregular disconnected creases..................... *arcuatus*, p. 363.
      - d^2. Size medium or small; membrane rather thin, often translucent. R=1.3 r; deposits present or absent; abactinal surface swollen and more or less warty in adult.
        - e^1. Paxillæ with high pedicel and five to fifteen (five to seven in Alaskan specimens) spines; suboral spine slender cylindrical; muscle bands connecting tips of paxillar spinelets; aperture slits small; oral spines six or seven; no deposits in supradorsal membrane; lateral fringe not defining ambitus.................................... *pulvillus*, p. 358.
        - e^2. Paxillæ low, with low pedicel and five to seven short spines; suboral spine with three sharp edges; no muscle bands connecting tips of paxillar spinelets; aperture slits unusually large; oral spines five; in supradorsal membrane deposits in the form of branched rods; lateral fringe defining ambitus.................................. *temnochiton*, p. 355.
    - c^3. Oral spines three, each series independently webbed; abactinal surface not much elevated and not at all warty.. *multispinus*, p. 359.
- a^2. Rays six, seven, or eight, very rarely nine; lateral fringe when evident narrow, defining ambitus; supradorsal membrane, actinolateral membrane, and webs heavy, spiracula numerous; abactinal surface rough and spiny; adambulacral spines four to seven; oral spines five or six, completely webbed. R=1.4 to 1.65 r.. *obscurus*, p. 363.

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[a] I have not included in the key Verrill's *Pteraster hebes* (1909*a*, p. 61), as I am not sure that it is a *Pteraster*. Professor Verrill has sent me two views showing the lateral and abactinal surfaces. The creature greatly resembles a *Diplopteraster*. The type lacked mouth plates, and the presence of muscle bands and spiracula in the supradorsal membrane is not indicated. If it is a *Diplopteraster* it would seem to be distinct from *multipes*. (Departure Bay, British Columbia, 23 fathoms, mud and sand.)

PTERASTER MILITARIS (O. F. Müller).

Pl. 98, figs. 1, 2.

Asterias militaris O. F. Müller, Zoologiæ Danicæ Prodromus, 1776, p. 234.

Asteriscus militaris Müller and Troschel, System der Asteriden, 1842, p. 44.

Pteraster militaris Müller and Troschel, System der Asteriden, 1842, p. 128, pl. 6, fig. 1*a* and *b*.—Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 167.

Pteraster aporus Ludwig, Echinodermen des Beringsmeeres, Zool. Jahrb., Abth. f. Syst., vol. 1, 1886, p. 293; Fauna Arctica, vol. 1, 1900, p. 470, footnote.—Clark, Bull. Mus. Comp. Zoöl., vol. 51, No. 11, 1908, p. 287 (key).

For an extensive list of references (none referring to the region covered by this report), see Ludwig, Arktische Seesterne. Fauna Arctica, vol. 1, p. 469.

Diagnosis.—Rays five. R = 2 to 2.5 r. Form stellate, rays evenly tapered, often slender at tip; supradorsal membrane fairly thick, without muscle bands, crowded with calcareous deposits in the form of minute very spiny fenestrated or reticulate bodies; spiracula few, fairly large, scattered whole length of ray abactinally and on sides; pedicels of pseudopaxillæ low, slightly higher than broad, with three to five slender spines. Adambulacral plates, proximally, with a transverse webbed comb of seven to nine spines (according to size of specimen), the free edge of web being slightly thickened, undulating, and continued outward as a ridge on the actinolateral membrane. Mouth plates with six to eight webbed marginal, and a single stout suboral spine, sheathed in membrane, and with a clear glassy tip. Actinolateral membrane narrow with a free margin.

Notes on North Pacific specimens.—An example, station 2846, has the following measurements: R = 75 mm.; r = 33 mm.; R = 2.2 + r; breadth of ray at base, 38 mm. A specimen from station 3445 is about the same (large) size.

The calcareous deposits in the supradorsal membrane can be readily seen with a strong glass, without clearing. The membrane itself is fairly thick, especially in the large example from station 2846, and is wrinkled more or less. The spines form only slight protuberances. The adambulacral combs are very regular, and the manner in which their web is continued laterally across the actinolateral membrane is characteristic of all the Pacific specimens. In very small examples this continuation is for only a short distance toward the margin, but in the large ones it forms a ridge nearly to the border. In three specimens accidentally dried these ridges are largely obliterated. The inner adambulacral spine is very short, the next one or two successively longer, so that the third or fourth is nearly as long as the longest, which are the following four or five. The large specimens have eight or nine adambulacral spines, while the small ones have about seven on the proximal half of ray. None of the spines have a terminal membranous sacculus as in *Pt. jordani*, but the edge of the web is, in life, slightly thickened and emarginated between the spines as in *Pt. stellifer* Sladen. The only Atlantic specimen of *militaris* available (from Bay of Fundy) has stouter adambulacral spines, six or seven in number, but the specimen is small (R = 30 mm.). The mouth plates have six to eight slender graduated webbed marginal spines, but the companion combs are not joined. The long inner spine is longer than the median suture of jaw plates. The suboral spine is clavate, pointed, very much heavier than any other spine, has a glassy distal part, and is normally sheathed in membrane. In the largest specimen this spine has a length of 7 mm., and equals the inner marginal spine. It will be seen that there may be two more mouth spines than is usual in smaller Atlantic specimens. However, a specimen (R = 35 mm.), from station 4772 has six mouth spines as also one from Kadiak (R = 18 mm.) while a young example from station 2857 (R = 10 mm.) has five adambulacral and five mouth spines. The ridges of tissue continuing the furrow webs onto the actinolateral membrane are less developed in the Bay of Fundy example, but the North Pacific specimens vary somewhat in this character, which Sladen emphasizes for his variety *prolata*.

Type-locality.—Norway (not formally stated in the Zoologiæ Danicæ Prodromus, but Denmark and Norway are to be understood; the species does not occur off Denmark).

Distribution.—This circumpolar species, heretofore not certainly known from this region,[a] evidently has, like so many other forms, invaded the North Pacific via Bering Strait. It ranges south to Washington, and from shallow water to 344 fathoms. Ludwig (Fauna Arctica, vol. 1, p. 470) summarizes the distribution as follows: East coast of North America from Cape Cod to the Gulf of St. Lawrence, north through Davis Strait and Smith Sound to Grinnell Land, reaching the most northerly station in lat. 79° 40′ N.; Greenland, Jan Mayen, Spitzbergen, Edgeland, and west of West Spitzbergen; south to Faroe Channel, and the Norwegian coast (Finmark to Bömmelfjord); eastward from Finmark to Barents Sea, Murman coast, and Kara Sea to Cape Tscheljuskin (longitude 116° E.). From here it evidently ranges to Bering Strait, although there are no records.

Specimens examined.—Nine, from the following stations:

Specimens of Pteraster militaris examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2846	South of Unimak Island, Alaska	44	gravel	1	U. S. Nat. Mus.
2857	Near Afognak Island, Alaska	51	gray sand, broken shells	1	Do.
3213	Near Unimak Island, Alaska	41	black sand	1	Do.
3445	Straits of Fuca, Washington	100	rocky	3	Do.
	Kadiak Island			1	Do.
4772	Bowers Bank, Bering Sea, north of Andreanof Island.	344	green mud, brown sand	1	*Albatross*, 1906.
4780	Near Agattu Island, Aleutians	70	green sand, pebbles	1	Do.

Remarks.—The presence of this species in the North Pacific is not surprising when considered in connection with *Diplopteraster multipes*, *Pseudarchaster parelii*, *Henricia sanguinolenta*, *Leptychaster arcticus*, and others.

I think there is little doubt that *Pteraster aporus* Ludwig is an abnormal example of *militaris*. In all respects, except in the absence of the osculur orifice, the description given by Ludwig admirably fits *militaris*. Ludwig's specimen came from Bering Sea.

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[a] Ludwig, Fauna Arctica, vol. 1, p. 470, states that *Pt. aporus* is perhaps a synonym of *militaris*

PTERASTER TRIGONODON Fisher.

Pl. 99, figs. 1, 2; pl. 115, fig. 2; pl. 116, figs. 2, 2*a*.

Pteraster trigonodon Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 168.

Diagnosis.—Rays five. R = 30 mm.; r = 16 mm.; R = 1.87 r. Breadth of ray at base 18 mm. General form stellate with angular interbrachial arcs. Disk moderately high; vertical diameter about two-thirds breadth of ray. Supradorsal membrane thin, without definite reticulations; calcareous deposits abundant, in the form of irregular spiny rods; spiracula numerous, large; pseudopaxillæ with high pedicels and six divergent spines; five adambulacral and five webbed marginal mouth spines; aperture papilla very broad; suboral spine very large, sharp, and three-edged; actinolateral membrane narrow, not defining ambitus.

Description.—Supradorsal membrane thin and translucent, the minute calcareous bodies showing under a moderate magnification; no regular reticulations, but fine muscle fibers proceed radially from the tips of the abactinal spines which push up the supradorsal membrane, giving the surface a papillose appearance. Spiracula conspicuous, numerous, but not uniformly distributed, although occurring everywhere on the abactinal and lateral surfaces. Some of them seem to have been enlarged by the stretching of the membrane. Here and there six or eight form a circle around the central spine of a paxilla. Membrane contains a multitude of minute calcareous bodies in the form of very irregular branched spiny rods, fenestrated spiny bodies, or irregular plates with one or two perforations and long spines attached. Each pseudopaxilla consists of an elevated slender pedicel about 2 mm. high, surmounted by a central spine and a circle of five around it, all slightly shorter than the pedicel, and forming the slight protuberances on the supradorsal membrane. Osculum large.

Ambulacra narrow, feet in two rows. Adambulacral plates with a curved transverse fan of five spines, the innermost shortest (one-half or two-thirds the longest), thence increasing in length to the outermost, which is usually longest and situated close to the actinolateral membrane. As in many species of the genus, the inner end of the series curves aborally. There may be four spines, especially far along ray. The web is deeply emarginate between the spines, and does not extend laterally on the actinolateral membrane. Aperture papilla wider than usual in proportion to length and with a very convex free aboral edge. Aperture at base of outer comb spine and about one-half its length.

Mouth plates rather narrow, each with a prominent central elevation or boss for the large actinal or suboral spine. This is one and one-half to nearly twice as long as the longest marginal spine, sharp, very heavy, and with three wide lateral flanges or edges, so that the spine has three concave faces, appearing like a miniature spear-head. Marginal spines five, graduated toward the innermost, which is about as long as the interradial dimension of plate; all are united by membrane, but companion combs are independent.

Actinolateral membrane narrow, with a narrow free border which does not define margin of ray when viewed from either surface. Actinolateral spines gradually decreasing in length; proximally about twice as long as outer adambulacral spine.

Type.—Cat. No. 27790 U.S.N.M.

Type-locality.—*Albatross* station 4427, off Santa Cruz Island, California, 447 to 510 fathoms, black mud, rocks.

Distribution.—Known only from type-locality.

Specimen examined.—The type.

Remarks.—This species, which stands about halfway between those which are stellate and those which are more or less pentagonal, bears superficially more resemblance to *militaris* than to any other form, especially as there are spiny often fenestrated calcareous bodies in the supradorsal membrane. The differences are important, however. In *trigonodon* the stalk of each paxilla is high (not low) and crowned by six (not three to five) spines shorter than pedicel; supradorsal membrane is thin in *trigonodon*, and the deposits are not so crowded. The adambulacral and marginal mouth spines are fewer (five, not six to eight), and the suboral spine is very large and of a special three-edged form, not cylindrical, as in *militaris*.

PTERASTER GRACILIS (Clark).

Retaster gracilis CLARK, Proc. Boston Soc. Nat. Hist., vol. 29, No. 15, May, 1901, p. 326, pl. 3, figs. 3 and 4.

The status of this species is somewhat doubtful. The two specimens are probably young, and, coming as they do from Puget Sound, might be considered as immature *tesselatus*. This form, however, differs from young *tesselatus* in having a very thin and delicate supradorsal membrane, longer rays (R = 2 r), and only two oral spines. The spiracula are fewer.

Diagnosis.—Rays five. R = 18 mm.; r = 9 mm.; R = 2 r. Breadth of ray at base equals r. Disk depressed, 6 to 8 mm. high. Supradorsal membrane very thin and delicate; tips of spines from the edges of the paxillæ connected by delicate lines giving abactinal surface a reticulated appearance; no spicules; spiracula quite numerous, six to ten in each mesh of reticulum; paxillæ high, with six or more (often many more) spines surrounding edge, and several smaller ones erect in middle; oscular orifice small. Adambulacral plates with five webbed spines arranged in a row at right angles to furrow. Of these the first is very small, the second larger, the third still larger, the fourth still larger, the fifth equals the third. Actinolateral spine slightly longer than longest adambulacral; actinolateral membrane with a free margin, narrow. Aperature papillæ very small, free only on one side. Mouth plates prominent, each with two marginal spines united by a membrane, and a very large free spine on oral surface near base, pointing downward and outward. Ambulacra broad; feet comparatively few, in two rows. Color, light brownish gray, darkest on disk, lightest near tip of rays.

Type.—Said to have been sent to Columbia University, New York; not to be found, 1910.

Type-locality.—Probably Puget Sound, Washington.

Remarks.—This species is known only from the two specimens described by Clark. Even the locality is doubtful, inasmuch as the specimens were not labeled, and the collection contained several species evidently from some locality south of the United States.

PTERASTER JORDANI Fisher.

Pl. 100, fig 2; pl. 101, fig. 1; pl. 117, figs. 1, *1a–b*.

Pteraster jordani Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 314; Ann. and Mag. Nat. Hist., ser. 8. vol. 5, Feb., 1910, p. 67.—Clark, Bull. Mus. Comp. Zoöl., vol. 51, No. 11, April, 1908, p. 286;

Diagnosis.—Similar in general form to *Pteraster militaris,* but supradorsal membrane lacking spiny calcareous bodies, tube feet in four instead of two rows, only three or four adambulacral spines, four mouth spines, and two (one to three) paxillar spines. R = 2 r.

Description.—Rays five. R = 75 mm.; r = 37 mm.; R = 2 r. Breadth of ray at base, 37 to 42 mm. Thickness of ray at base, about 28 mm. (type).

Form stellate, depressed; abactinal surface of rays and disk convex, actinal surface subplane; edges of ray rounded; rays tapering, with fairly straight sides, bluntly pointed, though sometimes swollen near tip and the extreme tip recurved, giving an entirely different appearance; interbrachial angles obtuse; a well developed lateral fringe present, though actinolateral membrane is narrow.

Supradorsal membrane rather thin, with no deposits of calcareous matter; paxillar spines very prominent; two spines to each pseudopaxilla (sometimes one or three), one considerably longer than the other, protruding 3 or 4 mm. above general level of the membrane, but carrying the latter with it; pedicel very low, and the spine correspondingly rather longer than usual in this genus; fine crisscrossing muscle fibers exceedingly abundant, and the summits of the paxillar spines connected by faint muscular bands, which are nearly invisible in the type-specimen but show with some distinctness in a smaller example; in the irregular meshes thus formed one to three large spiracula, these often absent; oscular orifice rather small, though variable in size; valves with a much higher and stouter pedicel than other pseudopaxillæ, and with about fourteen spines in two series on top of pedicel, all united by single membrane. The pedicel is about 2 mm. high in the midradial region of the type, the entire pseudopaxilla being about 11 to 12 mm. high. The papulæ extend about 5 mm. up the pseudopaxilla and have numerous short lobes at the top.

Adambulacral plates with a transverse series of three spines and one spinelet, united by a web; inner member of the series quite small and situated slightly aborad from the others; the next three are two to five times longer, and increase slightly in size outward, being united by membrane nearly to their tips, which are capped by a membranous sacculus; outer spine close to the corresponding actinolateral spine, to which it is united by membrane. Aperture papillæ prominent, jawbone-shaped, free on the aboral margin. On a smaller specimen the inner small spinelet is absent, and in the type it is sometimes absent, especially on plates beyond the middle of the ray. A specimen from off the coast of Washington also has three spines on most of the plates. Thus the combs may contain three long and one shorter spinelet or three long subequal spinelets only. The aperture papilla is not tented over by an auxiliary membrane, forming a special pocket between each pair of adambulacral combs. (See next species.)

Armature of mouth plates consisting of a marginal series of four spines and spinelets, the inner long and slender, the next nearly as long, and the outer two much shorter; inner three united by membrane, and usually also the whole four, but the outermost, which is shortest, sometimes stands alone; on the actinal surface commonly one long, slender spine about the size of the inner marginal, with which it stands in a linear series, directed over the outer end of the plate; this spine entirely free from the others. Sometimes there are only three marginal spines. The outer end of the combined mouth plates forms a peak in the center, the median suture sloping upward at a rather steep incline.

Actinolateral membrane narrow, only a trifle wider than furrow at base; spines short, the ninth or tenth the longest; for a considerable distance along ray they shorten only slightly or not at all. Membrane rather thin, forming a lateral fringe with an undulating edge. In some states of contraction this edge is free from the supradorsal membrane for one-third or one-fourth of its width.

Color in life, "dragon's blood" red.

Anatomical notes.—Hepatic cœca relatively enormous, extending to tip of ray, the interior a very spacious cavity from which food is probably absorbed. Between the large dorsal stomach and the anus is a spacious saclike intestine with wrinkled walls which probably function as the intestinal cœca of other forms. There is a powerful sphincter between the dorsal stomach and intestine. Dorsal stomach spacious with large dorso-ventral slits opening into each of the ten hepatic cœca, which are connected with the first ambulacral ossicles by strong bands of muscle, probably to draw the cœca toward the mouth when the stomach is thrown out. The first ambulacral ossicle is very large and arched. To it are attached along the inner face numerous muscles apparently protractors and retractors of the ventral or eversible stomach. The first tube foot has a single large ampulla, the succeeding tube-feet have two. The upper ends of the ambulacral ossicles are strongly imbricated and are very flaring. Tube feet with large sucking disks, in two zigzag or virtually four series; alternate pores are placed nearer the adambulacral plates so that the feet are really four ranked. No Polian vesicles; madreporic canal rather long and sinuous. Interradial septa of tough membrane, attached to either side of which is the gonad, forming a large much branched tuft. Gonads packed with sperm.

Abactinal plates with four long slender arms widening at the end. These overlap the lobes of adjacent plates and form square papular areas.

Type.—Cat. No. 22343, U. S. N. M.

Type-locality.—*Albatross* station 4354, off San Diego, California, 646 to 650 fathoms, green mud.

Distribution.—From northern Lower California to Washington, in 266 to 984 fathoms, on mud or sand.

Specimens examined.—Eleven, from the following stations:

Specimens of Pteraster jordani examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
2919	Near Los Coronados Islands, Lower California.	984	gray mud	2	U. S. Nat. Mus.
2948	Off Santa Cruz Island, California	266	gray sand, gravel	1	Do.
3075	Off Sea Lion Rock, Washington	859	green mud	1	Do.
3104	Off Half Moon Bay, California	391	coral	1	Do.
3346	Off Tillamook Bay, Oregon	786	green mud	1	Do.
4354	Near San Diego, California	646–650	do	1	*Albatross*, 1904.
4405	Between San Clemente and Santa Catalina Islands, California.	654	do	1	Do.
4412	Between Santa Catalina and Santa Barbara Islands, California.	274	do	1	Do.
4415	do	638	do	1	Do.
4421	Between Santa Barbara and San Nicholas Islands, California.	291	do	1	Do.

Remarks.—*Pteraster jordani* is a well-characterized species, having a rather thin supradorsal membrane lacking calcareous deposits, but possessing faint muscle bands connecting the two paxillar spines. The pedicels are very low and the spines correspondingly long, being six or seven times the length of the former. Tube feet are crowded in four rows, and the adambulacral combs have only three or four slender spines, of which the inner is commonly shorter than the rest. From *Pteraster militaris* the species is readily distinguishable by the absence of copious supradorsal calcareous deposits, fewer adambulacral and mouth spines, fewer paxillar spines, and in having four-ranked instead of two-ranked tube feet.

Attention should be called to the fact that the individual dissected was a male and that it was not different from the rest. The suggestion has been made[a] that in the Pterasteridæ the male may be some entirely different looking animal, perhaps now described as a different species. Such is certainly not the case.

PTERASTER MARSIPPUS Fisher.

Pl. 100, fig. 1; pl. 101, fig. 2; pl. 115, fig. 4; pl. 116, fig. 1.

Pteraster marsippus FISHER, Ann. and Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 168.

Diagnosis.—In general appearance and proportions similar to *jordani;* differs in having three shorter paxillar spines; sparse calcareous deposits in the form of simple straight rods of small size in supradorsal membrane; proximally five adambulacral spines (far along ray only four) and especially in having the aperture papilla partially tented over by a membrane passing from one comb to the next, and merging outwardly with the actinolateral membrane. A shallow side pocket is thus formed at the mouth of which is the aperture papilla. No spiracles. Type, R = 100 mm.; R = 40 mm.; R = 2.5 r. Breadth of ray at base, 45 mm. R varies to 1.8 r.

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[a] Lang, Text-book of Comp. Anat. (English translation), Pt. 2, 1896, p. 503.

Description.—This form is evidently a northern representative of *Pteraster jordani*, and without careful examination the two might be easily confused. The paxillar spines are not, however, so long as in *jordani*, although the pseudopaxillæ have the same character. The spines are 7 or 8 mm. long, and one is commonly slenderer than the other two; pedicel about 1 to 1.25 mm. high. In the alcoholic specimens the supradorsal membrane is smooth, fairly thick, and few spines protrude through. At any rate, it has not a rough, swollen, or warty appearance. A piece of the membrane cleared shows in scattered places a few minute straight or slightly curved, sometimes incipiently branched, rods, wholly unlike the crowded spiny deposits of *militaris*. Spiracles so few or inconspicuous that none can be detected. The supradorsal membrane is decidedly thicker than in *jordani*. Osculum as in *jordani*, each valve with about fourteen spines in two rows.

Proximally the adambulacral plates have five long, slender spines heavily sheathed and capped by a sacculus, and united by a membrane which joins the actinolateral membrane usually beyond the end of the outermost spine. The outer part of successive webs is joined by a slight horizontal membrane (not present in *jordani*), which forms a sort of lateral cul-de-sac at the mouth of which is the aperture and its papilla (similar to those of *jordani*). Far along the ray each comb has four spines; proximally the first spine is sometimes much shorter than the second, sometimes nearly as long. On account of the four-ranked tube feet, alternate adambulacral plates and armature are crowded back just a trifle. In *Diplopteraster* this crowding is carried farther, and the alternate adambulacrals have a less number of spinelets.

Mouth plates similar in form to those of *jordani;* marginal spines five, united by membrane, rapidly graduated in length from the long (10 mm.) inner to the short (2.5 to 3 mm.) outer; suboral spine slender, as long or longer than inner marginal, just behind which it stands.

Actinolateral membrane narrow and similar to that of *jordani*.

Type.—Cat. No. 27791, U.S.N.M.

Type-locality.—*Albatross* station 4784, near Attu Island, Aleutians, 135 fathoms, coarse pebbles.

Distribution.—Bering Sea, 52 to 351 fathoms, on gravel.

Specimens examined.—Twenty, from the following stations:

Specimens of Pteraster marsippus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection
		Fathoms.			
2842	Near Unalaska	56	pebbles	1	U. S. Nat. Mus.
3223	do	56	black pebbles	2	Do.
3486	West of Pribilof Islands	150	green mud, fine sand	1	Do.
3330	Near Unalaska	351	black sand, mud	3	Do.
3500	South of Pribilof Islands	121	fine gray sand, gravel	1[a]	Do.
4779	Near Semisopochnoi Island, Aleutians.	52	fine gravel	2	*Albatross*, 1906.
4784	Near Attu Island, Aleutians	135	coarse pebbles	3	Do.
4792	Near Bering Island, Commander Islands.	72	pebbles	5	Do.

[a] Two others probably from this station, label lost during earthquake 1906.

Remarks.—*Pteraster marsippus* differs from *jordani* in a number of details mentioned in the diagnosis. The calcareous microscopic rods in the supradorsal membrane are not found in *jordani*. In young *jordani* the spiracula are readily seen, while in *marsippus* they can not be detected. Neither have I been able surely to make them out in the adult. The additional mouth and adambulacral spine seems to be a constant difference, and especially the little side pocket just back of the aperture papilla, between any two fans of spines. This disappears in dried specimens. Unique examples of *Pteraster* should never be dried, as many valuable characters of the membranes are obliterated, never to be restored. A dried *Pteraster* is comparable to a dried fish; neither is a satisfactory verisimilitude of the live object.

From *Pteraster militaris*, which dwells in the same region and is similar in proportions, the present species differs in having four-ranked tube feet (except young), in lacking the crowded deposits in the supradorsal membrane, and in having fewer adambulacral and mouth spines. The actinal mouth spine is slenderer than in *militaris*, which also does not possess the little pockets between the outer ends of the adambulacral combs.

PTERASTER COSCINOPEPLUS Fisher.

Pl. 102, figs. 1, 3; pl. 116, fig. 4.

Pteraster coscinopeplus FISHER, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 169.

Diagnosis.—Stellato-pentagonal. R = 30 mm.; r = 21 mm.; R = 1.4 + r. Breadth of ray, omitting lateral fringe, 22 mm.; with lateral fringe, 25 mm. Supradorsal membrane without special muscle bands connecting summits of spines, but with a fine reticulation; spiracula very numerous, small; no spicules; paxillæ with high pedicels and six to eight spines; actinolateral membrane very wide, the free border defining entire ambitus; six webbed adambulacral spinelets; one very slender suboral spine; six slender free marginal mouth spines.

Description.—Abactinal surface covered with protuberances, the ends of the paxillar spines. Membrane moderately thick, slightly translucent, without coarse muscular reticulations, and without calcareous deposits, but with a fine reticulum of muscle fibers, the tiny not well-defined meshes of which inclose the small spiracula, one to a mesh. The fine fibers radiate from the summits of the spines, crisscrossing in every direction. Spiracula very numerous and small, occurring in short rows between the spines, or radiating from the central spine of a group or in a circle about a spine; much more numerous than in *trigonodon*. Pedicels of pseudopaxillæ relatively high (3 mm.), of about the same proportions as in *trigonodon*, and much higher than in *militaris*, *jordani*, and *marsippus*. Spines six to eight to each pseudopaxilla, subequal, and about as long as the pedicel. Osculum large, surrounded by many spines.

Ambulacra of medium width; tube feet biserial, not crowded. Adambulacral spines six, the inner the shortest and set aborally to the rest; the second about twice as long, the third slightly longer; the next three subequal; the outermost, or next one, longest. Web slightly emarginated, the spines having a blunt membranous tip; web extends a slight distance beyond end of outermost spine on actinolateral membrane. Aperture papilla longer than wide, with slightly convex aboral border; the aperture is at the base of the outermost adambulacral spine, and is less than one-third its length, shorter even than the small papilla.

Mouth plates with six slender independent marginal spines (no web), the inner the longest, and longer than the interradial diameter of plates, the outer very short, the others evenly and rapidly graduated between. The single suboral spine is very slender and a little longer than inner marginal spine.

Actinolateral membrane very broad, the conspicuous lateral fringe extending 1 to 3 mm. beyond the border of ray. The spines are longest at about the middle of ray (seventh to ninth spine); thence they decrease rather evenly to the tip, the fringe always defining ambitus.

Type.—Cat. No. 27792, U.S.N.M.

Type-locality.—*Albatross* station 2925 (probably), off San Diego, California, 339 fathoms, mud. The bottle in which this specimen was received was broken by the earthquake of 1906; the specimen was found beside the above label and the remnants of the bottle.

Distribution.—Off southern and central California, 287 to 1,062 fathoms.

Specimens examined.—Three; besides the type, one from station 4339, off San Diego, California, 287 to 369 fathoms, green mud; one from station 4537, off Monterey Bay, 1,062 fathoms, hard sand.

Remarks.—This species is related to *Pt. multispinus* Clark, *Pt. reticulatus* Fisher, and *Pt. multiporus* Clark, the first from Washington, the second from the Hawaiian Islands, and the third from Sagami Bay, Japan. From *multispinus* the present form differs in having five free slender mouth spines (not three united by membrane), in having a slender suboral spine, much more numerous spiracula, fewer paxillar spines (not eight to ten or more), and apparently differently formed aperture papillæ (in *multispinus* "nearly free on both sides"). From *reticulatus*, *coscinopeplus* differs in being more pentagonal in form, with a very much wider actinolateral membrane, and in having slenderer suboral spines (these heavy and club-shaped in *reticulatus*), no supradorsal reticulations, fewer paxillar spines, which consequently form a less closely papillated dorsal surface, and in having many more spiracula of a smaller size. The adambulacral armature differs chiefly in size, the fans being larger (and spines longer) in *coscinopeplus*. From *multiporus* this species differs in having a much wider actinolateral membrane (it is narrow in *multiporus*), higher paxillæ with fewer spines, and in having the mouth spines free, not the whole twelve (six of each plate) united by a continuous membrane.

PTERASTER TEMNOCHITON Fisher.

Pl. 103, figs. 2, 3; pl. 115, fig. 3, pl. 116, figs. 3, 3*a*.

Pteraster temnochiton Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 169.

Diagnosis.—Rays five. R = 21 mm.; r = 16 mm.; R = 1.3 + r. Breadth of ray at base, without lateral fringe, 9 to 11 mm.; with lateral fringe, 12 to 12.5 mm. General form stellato-pentagonal; interbrachial arcs shallow; lateral fringe defining ambitus; pseudopaxillæ low with five to seven spines; no reticulation; groups of spines independent and spaced; scattered, branched, irregular rods in membrane;

adambulacral spines five or four, webbed, the outer standing perpendicular, not subparallel to actinolateral membrane, which is wide; apertures long; aperture papillæ slender, sharp, with slightly convex aboral margin; oral spines five, slender, all ten united by continuous membrane; suboral spine sharp, three-edged, much heavier than oral spines.

Description.—Abactinal surface very arched and swollen by reason of the rays being more or less drawn together ventrally, and the actinal surface correspondingly concave. Supradorsal membrane rough by the *spaced* groups of paxillar spines, these groups of five to seven forming a slight or decided protuberance, the membrane between the groups being smooth and everywhere punctured by very numerous fair-sized spiracles, the whitish sphincters of which clearly define the edges. Pale muscle fibers meander here and there through the translucent membrane, but there are no discoverable muscle bands running between the tips of the spines. It should be added that the spiracles occur also among the spines, but are not more abundant than in the considerable space between the different groups. In other words, the groups are not crowded together, but are well enough spaced to be counted. Unlike *pulvillus,* the pedicel of each pseudopaxilla is low, scarcely if any higher than wide, with a crown of five to seven diverging slender spinelets, of which one commonly stands in the center of a circle of four to six; spinelets about 2.5 mm. long, and the pedicel about 0.75 mm. high. The whole paxilla is thus low, so that the supradorsal membrane is not much raised above the abactinal surface. Paxillæ with strong lobes (four to six). Membrane with scattered spicules in the form of crooked rods with irregular branches along the sides, these sometimes anastomosing and forming loops. There is no regularity in the form of these rods, which are not crowded as in *militaris.* They are never in the form of fenestrated bodies and are more like those of *trigonodon* than *militaris,* though simpler, but yet not so simple as those of *marsippus.* The arcade-like space beneath the supradorsal membrane is filled with embryos oriented with either the dorsal or ventral surface uppermost. The specimen is a female. Osculum rather small.

Ambulacra narrow; feet in two rows. Adambulacral armature consisting of a series of five (distally four) webbed spines curved aborally on the inner end; the inner very short, the next nearly twice, the third about two and a half, and the fourth about three and a half times length of inner, the fifth subequal to fourth. Membrane deeply emarginate between spines which are not prolonged in a membranous sacculus. A peculiarity of this species is that the outer spine is not close to the actinolateral membrane, but stands nearly perpendicular, with as much web between it and the membrane as there is between the fourth and fifth spines. Aperture papillæ long, slender, and sharp (about one-half length of outer spine), situated about half its length laterally from base of outermost spine. The aperture slit is unusually long, extending laterally beyond the edge of the papilla, especially on outer part of ray. The apertures form a conspicuous row of slits along the outer edge of the series of adambulacral fans.

Mouth plates with five marginal spines graduated fairly evenly from the long inner to the very short outer, the whole ten united by a continuous membrane extending to the tips of the spines. The spines are slender and slightly tapering.

The suboral spine is sharp and glassy, the outer half flaring, with three sharp edges and three concave faces which can be easily discerned even when the spine is sheathed in membrane. The shape of this spine, which is situated on a boss, at about the middle of the plate, is similar to that of *trigonodon*.

Actinolateral membrane wide, with a wide fringe defining the entire ambitus. About the seventh actinolateral spine is longest in type; thence they regularly and rapidly decrease in length toward the tip of ray. When viewed from above, the membrane projects a conspicuous distance (about one-sixth width of ray) beyond the edge of the supradorsal membrane. Edge of membrane scalloped; spines showing through membrane.

Color dirty whitish, or brownish gray in alcohol.

Type.—Cat. No. 27793, U.S.N.M.

Type-locality.—*Albatross* station 4784, near Attu Island, Aleutians, 135 fathoms, coarse pebbles.

Distribution.—Known only from the vicinity of the Aleutian Islands.

Specimens examined.—From type-locality, two; from station 3223, near Unalaska, 56 fathoms, black pebbles, three specimens.

Remarks.—Superficially, at least, this species resembles *pulvillus*, especially the abactinal view, the groups of spines forming slightly raised independent spiny protuberances. The differences are as follows: Low paxillar pedicels with spines much longer (reverse in *pulvillus*), no muscle bands between spines (figured in *pulvillus*), adambulacral spines fewer (five); aperture slits of a peculiar and characteristic form; mouth spines five; suboral spine not slender but stout and three-edged. The deposits in the supradorsal membrane may constitute a further difference (I have not seen Atlantic specimens of *pulvillus*). From *Pteraster obesus* Clark (Sagami Bay, Japan) *temnochiton* differs in having calcareous spicules in membrane, low paxillæ with fewer spines, fewer adambulacral spines (six or seven in *obesus*). In contrast to *temnochiton*, *obesus* has independent oral spines (five to seven), short actinolateral spines, so that the fringe is narrow and concealed from above. Even the suboral spine is different, that of *obesus* ending in a triangular point, while in *temnochiton* the spine is really three-edged for a considerable part of the length. The aperture papilla is small in *obesus*, and the aperture is not unusually large, as in *temnochiton*. From *trigonodon*, *temnochiton* differs in having a wide, not narrow, actinolateral membrane, differently formed deposits, low, not high paxillæ, slender and long, not short and thick aperture papillæ, in having the outer adambulacral spine distant from, not close to the actinolateral membrane, in having much more conspicuous apertures, in having companion combs of oral spines bound together mesially by a continuous web. The abactinal facies of the two is quite different; the lateral fringe, for one thing, does not define the ambitus in *trigonodon*.

PTERASTER PULVILLUS Sars.

Pl. 102, figs. 2. 4.

Pteraster pulvillus M. Sars, Översigt af Norges Echinodermer, 1861, p. 62, pl. 6, fig. 14–18; pl. 7; pl. 8; pl. 9, fig. 1–6.—Ludwig, Fauna Arctica, vol. 1, 1900, p. 470 (here is given an extensive list of references, referring to Atlantic and Arctic localities, but not to the region of this report, where the species has not heretofore been taken).—Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 168.

Two specimens from the vicinity of Bering Island are referred with some hesitation to this species. They have the following characters:

Diagnosis.—Rays five. R = 21 mm.; r = 16.5 mm.; R = 1.27 r. Form nearly pentagonal with breadth of ray at base about equalling minor radius; disk convex, uniformly roughened by prominent tips of paxillar spines; pseudopaxillæ with high pedicel and six, seven, or eight slightly shorter diverging spinelets, the tips of which are connected in the supradorsal membrane by rather faint muscle bands, about six radiating from central spine of each paxilla, the meshes thus formed containing one to three papular pores. No spicules in membrane. Osculum small, ambulacra narrow, feet in two rows. Adambulacral spines six proximally, then five, then four distally, the innermost much the shortest, the next to outermost longest; membrane emarginate between tips of spines, aperture papilla rather narrow and free along aboral convex border. Marginal mouth spines seven (six in a smaller specimen), slender, tapering, the inner very short; all fourteen united by a common web to tips; suboral spine a trifle longer than inner oral spine (which is longer than interradial diameter of plates) slender, glassy, sharp, encased in a pulpy sheath which makes it appear fairly robust. Actinolateral membrane narrow, about the fourth spine longest whence the rest gradually decrease in length to tip of ray, free edge of membrane narrow and slightly emarginate between tips of spines.

Color in alcohol dull yellowish gray or light yellowish brown.

Type-locality.—Three miles north of Bergen, Norway, 50 to 60 fathoms.

Distribution.—Ludwig (Arktische Seesterne, p. 471) summarizes the distribution as follows: Maine to Newfoundland (lat. 42° to 48° N.); on the Norwegian coast from lat. 60° N. to Finmark; Barents Sea; Murman coast; Matotschkin Strait and Kara Sea; Spitzbergen (to lat. 79° N.). To this must be added Bering Sea.

Specimens examined.—Two, from station 4792, near Bering Island, 72 fathoms, pebbles.

Remarks.—These two specimens do not seem to be typical, although I have had only the Latin diagnosis of Sars and a copy of figs. 2 and 9, pl. 7, and fig. 2, pl. 9, as a basis for comparison. According to Doctor Clark's key these examples would be *pulvillus*.

The differences seem to be as follows: fewer paxillar spinelets (eight to fifteen in the type), a weaker reticulation (according to Sars' pl. 7, fig. 2 the bands are quite heavy and the meshes contain one spiracle); more spiracula; the supradorsal membrane has not a number of humps due to more prominent paxillæ as shown by Sars' figure, but instead the surface is roughened all over by the prominent spines; the adambulacral spines are six only at the base of furrow near mouth plates; the mouth spines are seven. However, it may be stated that the character of the oral armature, paxillæ, and supradorsal membrane of the Bering Sea specimens agrees fairly well with Sars' diagnosis and figures.

PTERASTER MULTISPINUS Clark.

Pteraster multispinus CLARK, Proc. Bost. Soc. Nat. Hist., vol. 29, No. 15, May, 1901, p. 326, pl. 3, figs. 1 and 2.—FISHER, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 168.

Description.—Rays five. R = 27 mm.; r = 18 mm.; R = 1.5 r. Breadth of ray at base, 17 mm. Interbrachial arcs rather shallow. Disk almost flat, 10 mm. high, the rays not clearly marked off. Abactinal surface of rays almost flat; actinal surface flat, edges rounded. Supradorsal membrane thick, stout and apparently muscular with no signs of reticulations. Spiracula seem to be absent on disk, but abundant near tips of rays. Paxillæ high with numerous spines (eight to ten or more), those in the middle little more slender than those on edge of paxilla. On account of the abundance of paxillæ spines, it is almost impossible to determine whether the membrane contains any other calcareous bodies or not, but there seems to be none. Oscular orifice large, surrounded by long spines imbedded in the membrane. Ambulacral furrows broad; feet in two rows. Adambulacral plates with six spines arranged in a row at right angles to furrow and united by a delicate membrane. The outermost spine is clearly united to the fifth by this membrane, *and each series of spines is united by this membrane to the edge of the supradorsal membrane* (italics mine). Between each pair of outermost spines is a small sharp spine, the aperture papilla, which is nearly free on both sides. Mouth plates prominent, each with three marginal spines united by a delicate membrane, and with a very large free, superficial spine, placed near the base, and pointing downward and backward. Color in alcohol, grayish pink-purple. (Clark.)

Remarks.—The type, originally at Columbia University, New York, seems to have been misplaced. At least its whereabouts was not known in January, 1910. The specimen was collected by a party from Columbia University, presumably at Puget Sound, 1897. Nothing further is known of the species.

No mention is made in the description of an actinolateral membrane, which is therefore probably very narrow. The italicized portion of the above description would seem to indicate as much. As no lateral fringe is mentioned I am not certain whether this is present.

PTERASTER TESSELATUS Ives.

Pl. 104, figs. 1–5.

Pteraster tesselatus IVES, Proc. Acad. Nat. Sci. Phila., 1888, p. 421 (Kadiak Island).

Diagnosis.—General form very broadly stellate, as, for instance, R = 88 mm., r = 54 mm., R = 1.63 r (station 4222); disk high, rays short and thick, with straight or swollen sides and recurved blunt tip; interbrachial arcs angular broad; supradorsal membrane thick, spongy, marked by reticulations inclosing numerous small spiracula; spinelets not protruding as a rule; paxilla spinelets eighteen to twenty-six, the six or seven peripheral stouter, and slightly longer than pedicel; actinolateral membrane narrow, a slight fringe in young examples; adambulacral comb with five to seven webbed spines, the three or four outer subequal and longest; five to seven oral spines (usually six), both series united by continuous membrane; suboral spine heavier and longer than inner marginal oral, but slender; madreporic body with a tuft of spines.

Description.—The general form is somewhat variable, but the animal is very stout, and the abactinal membrane is more or less inflated, the creature resembling a stellate cushion. Supradorsal membrane thick, tough, and spongy, regularly reticulated, the quadrate or hexagonal areas in most individuals being better differentiated on sides of ray, and there containing twenty to thirty-five spiracula. No spicules in supradorsal membrane. Surface of membrane either smooth, or roughened and papillated by the paxillar spines. Very small specimens are relatively much rougher (though not invariably so) than the large ones, depending, probably, on the contraction of the membrane at death. (See "*Variations*," on p. 361.) Pseudopaxillæ very numerous, with a rather low pedicel which is shorter than the spines. Spines numerous, about twenty-six in full-sized specimens; of these, seven or eight thicker ones form a diverging group on the periphery, the rest being much slenderer, and delicate, and occupying the center. The membrane in which the spines are immersed forms seven or eight laminæ radiating from the center of the group and ending with each of the seven or eight peripheral spines. All spines are rather stouter at the distal end. The muscle bands, which show as reticulations exteriorly, hang down on the inner side of the supradorsal membrane like tiny partitions or curtains, so that the "ceiling" of the nidamental cavity is fenestrated. The seven or eight (fewer in small specimens) radiating spines with their laminæ of membrane rise in a quite regular manner and join these so that the appearance is that of a groined vault in miniature. Length of pedicel, about 2 mm.; length of spines, about 3 mm. Osculum conspicuous with a raised border.

Ambulacra narrow; feet large in two rows. Adambulacral combs, close together, in large specimens with seven spines (proximally at least), or six in medium-sized and small examples (five in some very small ones). Membrane slightly emarginated between spines, the four or five outer of which have swollen sacculated tips; the three or four outer subequal; the third from inner end slightly shorter, the second about half as long as third, and the first very short and placed aborally to the series. Occasionally five spines are long and subequal (in a series of seven), but four is the usual number, in large and medium-sized examples, and three in small ones. Outermost spine close to actinolateral membrane with which it is joined by membrane; aperture a little over half length of outer spine, the papilla narrow and with free aboral edge.

Mouth spines five to seven, usually six, the outer very short and the rest gradually lengthening to the inner, which is slightly longer than interradial diameter of plate; the whole ten to fourteen of each angle are united by a common membrane to tips. Suboral spine heavier and longer than any marginal spine, slender, subcylindrical, clear-tipped, pointed, and incased in heavy membrane.

Actinolateral spines very short, the proximal ones only one and a half to one and three-quarters times as long as outer adambulacral spine; consequently, the membrane is narrow and does not increase very much in width proximally. In large specimens this membrane is flush with the general actinal floor, there being no free edge or fringe except far along ray. In young examples and in dried specimens there is always a more or less marked free border to the actinolateral membrane.

Color in life, variable, generally bluish gray or dull purplish mottled with fawn color; a specimen from station 4235 was very light yellowish (yellowish white) in life, the tube feet canary yellow. The mottling usually persists in alcohol.

Anatomical notes.—Abactinal plates cruciform with four (or five) long slender truncate lobes. Madreporic body very convex, as high as wide, with a tuft of spines at the top ("pseudoplacote"). Anal opening very large, surrounded by a membranous periproct 11 mm. broad, and bounded by the five large radial (osculum) paxillæ. Anus opens from a spacious simple chamber with four short saccular diverticula. This chamber in turn connects with the dorsal stomach by a large aperture. Hepatic cœca large. Very strong muscles from the enlarged first ambulacral ossicle to stomach wall. Gonads interradial, in large tuft. Apparently no Polian vesicles; Tiedemann bodies large. First tube feet, on either side, with only one ampulla (as in *Pt. jordani*); the rest with two. Interradial septa membranous, tough.

Variations.—The Alaskan and British Columbian specimens vary slightly in proportions, some having more inflated and shorter rays than others. The tip of the ray is more or less upturned or reflected, so that the ends of the ambulacra assume a dorsal position. The degree of this upturning causes a variation in the length of rays; the extremes are about R=1.5 to 1.85 r; those less than 1.6 r are young; the usual is R=about 1.65 r. Besides a variation in color there is also a great difference in the texture of the supradorsal membrane. Usually it is only slightly roughened by the tips of the spinelets. The reticulation shows most plainly on the lateral and ventrolateral surfaces, and often not at all plainly on the dorsal surface. If the surface layer of the supradorsal membrane is much swollen, the reticulations are wholly or partly obliterated and the spiracula appear to open into fine furrows or creases. Variations in the adambulacral spines and actinolateral membrane have already been alluded to.

Type.—No. 292, Academy of Natural Sciences, Philadelphia.

Type-locality.—Kadiak Island, Alaska. The locality was omitted in the original description, but was recorded later.[a]

Distribution.—Bering Sea (Bering Island, Pribilofs, Hagemeister Island) south along the North American coast to Washington.

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[a] Proc. Acad. Nat. Sci. Phila., 1889, p. 175.

Specimens examined.—Thirty-nine, from the following stations:

Specimens of Pteraster tesselatus examined.

Station.	Locality.	Depth. *Fathoms.*	Nature of bottom.	Number.	Collection.
	Hagemeister Island, Alaska	8–15		1	U. S. Nat. Mus., W. H. Dall.
	Shumagin Islands, Alaska	48		1	Do.
	Unalaska, Alaska	Extra low water.		2	Do.
	Bering Island			2	U. S. Nat. Mus.
	Popof Straits, Shumagins			1	U. S. Nat. Mus., W. H. Dall.
	Victoria, British Columbia			1	U. S. Nat. Mus., C. F. Newcombe.
	Barclay Sound, British Columbia.			1	U. S. Nat. Mus., *Albatross*, 1889.
	Departure Bay, Nanaimo, British Columbia.			1	U. S. Nat. Mus., Geo. W. Taylor.
2862	Off Vancouver Island	238	gray sand, pebbles	1	U. S. Nat. Mus.
3213	South of Alaskan Peninsula (Sannak Islands).	41	black sand	1	Do.
3222	South of Unimak Island, Alaska.	50	do	1	Do.
3262	Near Unimak Island, Alaska	43	black stones, rocks	1	Do.
3274	South of Alaska Peninsula (east of Unimak Island).	19	black sand, shells	1	Do.
3461	Straits of Fuca, Washington	114	gray sand, gravel	1	Do.
3486	Bering Sea, west of Pribilofs	150	green mud, fine sand	1	Do.
4205	Vicinity of Port Townsend, Wash-	15–26	rocks, shells	2	*Albatross*, 1903.
4209	do	25	rocks, coarse sand, shells.	1	Do.
4222	do	39	gray sand, broken shells.	4	Do.
4235	Vicinity of Yes Bay, Behm Canal.	130–193	gray mud	1	Do.
4285	Chignik Bay, Alaskan Peninsula	31–59	gray sand, shells	1	Do.
4289	Uyak Bay, Kadiak	74–80	gray mud	2	Do.
4777	Near Semisopochnoi Island, Aleutians.	52	fine gravel	6	*Albatross*, 1906.
4779	do	54	broken shells, pebbles, sand.	4	Do.
4784	Near Attu Island, Aleutians	135	coarse pebbles	1	Do.

Remarks.—It may eventually be considered advisable to place this and the following form in the genus *Retaster.* Practically all the current diagnoses of *Retaster* read as if *Pteraster* never had a dorsal reticulum, or else as if deposits in the supradorsal membrane characterized *Pteraster.* Many species of *Pteraster* entirely lack the spicules. So far as the reticulum is concerned, the difference between the two genera is one of degree rather than kind. Species that may be considered typical members of *Retaster* are *capensis, cribrosus, gibber,* and *insignis.* These have the muscle bands conspicuously developed, dividing the membrane into areas sharply circumscribing the spiracula. Just this is found in *tesselatus*, but the muscle bands are not usually conspicuous, except on the sides of the body (and elsewhere in specimens in which the epidermis is more or less rubbed). The narrow actinolateral membrane is not characteristic of *Retaster*, since several undoubted *Pteraster* also possess it. All known *Retaster* (excluding *Diplopteraster*), however, have the narrow membrane.

In the following subspecies, or it may be, closely related species, the reticulations are not evident superficially in the unique specimen. Neither are the spiracula in circumscribed areas, as they should be in *Retaster*. It is this circumstance which has led me to keep both forms in *Pteraster*, although for several years I considered *tesselatus* a *Retaster*.

PTERASTER TESSELATUS ARCUATUS, new subspecies.

Pl. 103, fig. 1.

Diagnosis.—Similar to *Pt. tesselatus*, but arcuately pentagonal in form, with thick supradorsal membrane, without signs of reticulation; spiracula sunken in irregular creases. R = 46 mm.; r = 32 mm.; R = 1.44 r.

Description.—Supradorsal membrane rather thicker than in typical *tesselatus* and marked by fine, irregular, discontinuous, often branching, dark creases, into which open the spiracula. These are more prominent on the dorsal than lateral surfaces. Paxillar spines eighteen to twenty-four. Adambulacral spines five or six, of which three are usually long and subequal and the two inner decidedly shorter. Of the latter the innermost is about one-third and the second spine two-thirds the length of the third spine. Mouth plates with six marginal spines similar to those of typical *tesselatus;* suboral spine about as long as innermost marginal spine, and with a transparent, tapering, sharp tip.

Color in life, abactinal surface mottled with fawn color on a ground of bluish-gray or dull heliotrope purple; radiating from center are five narrow, dark, interradial patches extending halfway to margin, and five radial larger and lighter areas; outside of this is a stellate, irregular ring of dark, near ambitus. Actinal surface, actinolateral membrane vinaceous buff; interradial areas dull heliotrope purple (that is, outside of the narrow membrane); tube feet, yellowish.

Type.—Cat. No. 27794, U.S.N.M.

Type-locality.—*Albatross* station 4551, Monterey Bay, California, 56 to 46 fathoms, rocks.

Distribution.—Known only from the type, taken in Monterey Bay.

Remarks.—This form differs from northern *tesselatus* chiefly in the arcuately pentagonal form, generally one less furrow spine, and in having the spiracula in fine, dark furrows, which form disconnected, meandering, branched designs. The reticulations of the supradorsal membrane of *tesselatus* are not evident in *arcuatus*.

PTERASTER OBSCURUS (Perrier).

Pl. 105, figs. 1–4; pl. 106, figs. 1, 2.

Hexaster obscurus PERRIER, Comptes rendus, vol. 112, No. 21, May 1, 1891, p. 1227; Mém. soc. zool France, vol. 4, 1891] p. 267; Résult. camp. sci. du Prince de Monaco, fasc. 11, 1896, p. 41, pl. 3, figs. 1, 1*a*.—VERRILL, Trans. Conn. Acad., vol. 10, 1899, p. 221.—LUDWIG, Arktische Seesterne, 1900, p. 468 (distribution).

Pteraster (Temnaster) hexactis VERRILL, Proc. U. S. Nat. Mus., vol. 17, 1894, p. 275.

Pteraster hexactis DÖDERLEIN, Zool. Anz., vol. 22, 1889, p. 338.

Temnaster hexactis VERRILL, Amer. Journ. Sci., vol. 49, 1895, p. 202.

Pteraster obscurus DÖDERLEIN, Wiss. Meeresuntersuch., (N. S.) vol. 4, Abth. Helgoland, Heft 2, 1900, p. 213, pl. 8.—MORTENSEN, Meddelelser om Grønland, vol. 29, 1903, p. 77.

Pteraster octaster VERRILL, Amer. Journ. Sci., vol. 28, July, 1909, p. 61, fig. 1.

Diagnosis.—Rays six, seven, eight, or nine form[a]; robust, rays short, broad, and usually rigid; disk high; R = 1.4 to 1.65 r. Supradorsal membrane tough and thick, without reticulation superficially, without spicules, and with very numerous spiracula; sides of rays rounded; paxillæ stout with six to eight peripheral spines, one being considerably enlarged, and from four to eight slenderer central ones; peripheral spines give supradorsal membrane a bristling appearance; pedicel slightly higher than shorter spines; adambulacral spines four to seven, the innermost shortest, the others subequal, flattened, truncate, bound together by a very thick skin which is continued across actinolateral membrane as a low fold; actinolateral membrane thick, wide; lateral fringe narrow, usually defining ambitus; oral spines five or six, the two series webbed into a single scoop-shaped group at each mouth angle; suboral spine pointed, hyaline, shorter than inner flattened mouth spine.

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[a] Only one example, the young of an eight-rayed specimen.

Notes on North Pacific specimens.—Supplementing the description given by Verrill of a specimen from *Albatross* station 2433, off Newfoundland Bank (No. 12004, U.S.N.M.), 57 fathoms, the following notes based on specimens from Bering Sea and vicinity may be of value in showing the range of variation:

Perrier's type measured R=20 mm.; Verrill's, R=32 to 35 mm., r=22 mm., R=about 1.5 mm. The largest specimen from station 3285, with seven rays, has the following dimensions: R=82 mm., r=50 mm.±, R=about 1.6 r. The largest six-rayed specimen, station 3282, measures R=71 mm., r=43 mm., R=1.65 r; a small specimen, R=24 mm., r=17 mm., R=1.4 r. Twenty-one have six rays, two have seven, four have eight, and one young extracted from the nidamental cavity of an eight-rayed specimen has nine rays. The abactinal surface is well arched, the rays usually swollen and the actinal surface slightly sunken. The general appearance is shown by the figure.

The supradorsal membrane is very tough and opaque, with muscle fibers (when viewed from the inner surface), but not regularly reticulated. From the outside no muscle bands show at all. The surface is either uniformly papillated with the stout peripheral pseudopaxillar spines, or a few paxillæ cause the surface to be raised in warty humps (as shown by Perrier's figure), these latter in addition to the usual spiny appearance. Spiracula very numerous; and usually in large specimens groups or lines of two or more lie in furrows or dark creases of the skin. The smooth interradial grooves vary in width and length, but there are no slits such as Verrill found; these are formed periodically as he suggests. (See "*Young*," on p. 365.) Usually the area without spiracula extends about halfway from margin to osculum, and is very narrow. (See also Döderlein, 1889, 1900.)

Pseudopapillæ stout, shorter abactinally than laterally, with robust cruciform bases. Pedicel stout, abactinally a little higher than the spines. A specimen from 3251 has six to eight stout, often clavate, rough-tipped, blunt, slightly radiating, peripheral spines and often a stout central spine to each pedicel. Surrounding the central spine (between it and the peripheral six to eight) are from four to eight very much slenderer spinules, which do not, as a rule, push up the supradorsal membrane to an appreciable extent. One of the peripheral spines is usually much enlarged with a blunt clavate tip which shows more prominently from the outside, being thicker, heavier, and usually longer than the rest. The large seven-rayed specimen has the same structure. The enlarged peripheral spine being well marked and on some paxillæ greatly enlarged, especially on the dorsolateral surface of the rays. Tips of spines minutely roughened.

The largest six-rayed example has five spines in each of the adambulacral combs, except on outer part of ray where there are four. The inner is shorter than the outer three or four, which are subequal, or the outermost a trifle the longest as well as stoutest. The spines are flattened and vary in thickness in different specimens, being sometimes slightly tapered, sometimes not; tip of first spine bluntly pointed, rough, the rest rough, obtuse, or truncate. The membrane is thick and obscures the spines. The edge is emarginate between the spines and forms usually a rounded tip to each; from the outermost spine the fold extends across the actinolateral membrane as described by Verrill. Thus the space between each pair of combs is continued as a narrow sulcus toward and even to the margin, as well shown in the photographic figure and in Perrier's figure of a little specimen. The adambulacral structure does not differ in the large seven-rayed example except that proximally there are six spines. The outermost is bent away from the rest as described by Verrill in his type from off Newfoundland Bank. The tip of the spines, as in typical examples, is armed with minute thornlets and is more or less compressed and truncate. The number of adambulacral spines is variable in six-rayed examples, however, for a medium-sized specimen has seven, others six, some five, and small specimens four. The smaller seven-rayed examples have six spines proximally. Aperture short and rather broad with a very convex aboral border.

Mouth spines of the two plates united by a thick continuous web forming a spade-shaped group, five or six to a plate and decreasing very rapidly from the inner to the outer; the larger spines, especially the innermost, considerably flattened; the latter longer than interradial diameter of plate. Suboral spine stout, with a hyaline pointed tip, about equal to interradial diameter of plate, and therefore shorter than innermost oral spine.

Actinolateral membrane tough, and traversed by continuations of the adambulacral fans. The extent of the free border is variable. If the supradorsal membrane is swollen greatly the fringe is not apparent; otherwise it defines the ambitus, as shown in Perrier's figure. The actinolateral spines are stout, and hidden by the thick membrane. The tips however are visible, being heavy and truncate.

Young.—The large seven-rayed example had a young one in the act of escaping through a breach of the supradorsal membrane when killed. This opening is just above the actinolateral border and midway along the side of ray. The membrane was stretched and thin over that point. In one of the smooth interradial regions the membrane was found to be thin also, and a cut revealed two young ones beneath, actinal surface uppermost. The larger of these two has R = 10.5 mm., r = 7 mm. The one which was escaping has R = 7 mm. Both have six rays, although the parent has seven. The membranes of the young are thin, all the actinal spines being clearly visible. The lateral fringe is prominent. Adambulacral spines five, oral spines five; prominent paxillar spines (as seen from without) four or five; spiracula four or five over each paxilla, one spiracle between a pair of spines. The general appearance of this young one is exactly like that of a *Pteraster* with thin membranes. The six rays in the young shows that this is the fundamental number for the species, despite the seven of the parent.

The slits observed by Verrill are temporary only, and may occur elsewhere than in the interradial regions. They are probably formed periodically in other species of *Pteraster* also, and are the normal means by which the large young escape from the nidamental supradorsal cavity. The slits can not be regarded as a special generic character. The young when they leave the parent are essentially like the adult except in having more delicate membranes, fewer abactinal spines and spiracles. They are also exceptionally large, the largest one having a diameter of 20 mm.

Type.—Musée océanographique, Monaco (?).

Type-locality.—Off Newfoundland, 155 meters.

Distribution.—Bering Sea, from Bering Straits south to Bering Island, Kamchatka, and Unalaska; Spitzbergen (Döderlein), Greenland (Mortensen), Newfoundland (Perrier, Verrill). Evidently the species is circumpolar. The vertical distribution in Bering Sea is 17 to 85 fathoms; in the North Atlantic, 50 to 145 fathoms. The specimens from Bering Island were evidently washed ashore as they are much abraded.

Specimens examined.—Twenty-seven, from the following localities:

Specimens of Pteraster obscurus examined.

Station.	Locality.	Depth.	Nature of bottom.	Number.	Collection.
		Fathoms.			
	Bering Island, Commander Islands.			2 [a]	U. S. Nat. Mus., L. Stejneger
	Bering Strait, 12 miles east of King's Island.	17	mud	1 [a]	U. S. Nat. Mus., W. H. Dall, 1210 (6101).
3225	Near Unalaska	58	black sand	2	U. S. Nat. Mus.
3251	Bristol Bay, Alaska	37	fine gray sand	2	Do.
3265	Bering Sea, north of Unimak Island, Alaska.	38	black sand	9	Do.
3282	Bering Sea, north of Alaskan Peninsula (near Point Moller).	53	fine sand, green mud	5	Do.
3285	Bering Sea, north of Alaskan Peninsula (Cape Kutuzof).	35	gray sand	1 [b]	Do.
3505	East of Pribilof Islands, Bering Sea.	44	fine gray sand	1	Do.
3512	Bering Sea, north of Pribilof Islands	38	fine sand, green mud	1	Do.
3557	Pribilof Islands	26	sand	1 [a]	Do.
	Acc. No. 16889, U.S.N.M.			1 [b]	*Corwin*, Alaska, 1881.
	Acc. No. 15278, U.S.N.M.			1	*Corwin*, Alaska, 1884.

[b] Seven-rayed.

[a] Eight-rayed.

Remarks.—Perhaps the first specimen of this species ever taken was that collected by Dr. W. H. Dall near Bering Strait in 1874 (Cat. No. 6101, U.S.N.M.). The species was not described until seventeen years later, and not recognized by zoologists generally until after 1894 when Verrill described a specimen from off Newfoundland Bank (lat. 43° 05′ N.; long. 50° 43′ W.). Perrier's preliminary descriptions (1891) seem to have been overlooked, even by Perrier himself, for he did not include his new genus in the keys of the *Travailleur* and *Talisman* report, 1894.

The work of the *Albatross* in Bering Sea, and the Dall specimen, greatly increase the known range of this interesting form, which has hitherto been recorded only from scattered localities in the North Atlantic. All the Atlantic specimens of which I have seen any notices seem to be six- or seven-rayed, and smaller than the largest Bering Sea example. There is little doubt that the seven- and eight-rayed specimens belong to the same species as the six-rayed. The structural details are just alike; and what is conclusive is the fact that young of a seven-rayed specimen have six rays, while young of eight-rayed specimens may have seven rays.

The young grow to a large size before escaping, by rupture of the supradorsal membrane. The membrane first becomes thin over the young, which are usually found in the interradial region, but may occur also along the rays. The membrane has the same appearance, before rupture, that the dorsal integument of *Luidia* assumes before the autotomy of a ray. The fact that the young had its ventral surface close to the membrane, about to rupture, suggests that possibly its digestive juices may play a part in the process of escape. After the escape of the young the membrane closes, and the slit heals, causing probably the scarlike appearance of the interradial smooth areas.

This species stands quite alone, having no near relatives. Perrier, Verrill, and Ludwig place it in the monotypic genus *Hexaster;* Döderlein, Mortensen, and Hamann, consider that it belongs in *Pteraster.* Perrier and Verrill independently made the species the type of a genus, so that it may be well to examine the original descriptions. Omitting those characters of Perrier's diagnosis which apply equally well to *Pteraster*, the following remain: Six rays, actinolateral spines immersed in the ventral membrane, not extending beyond the border of the ray. The second character is nullified by Perrier's figure of the type. As a matter of fact, the lateral fringe is present, though not well developed. The supradorsal membrane has muscle fibers which are evident enough from the inner side; if these were not present how would the membrane assume so many different forms or attain such an unusual toughness and thickness? Most of Perrier's diagnosis applies equally well to *Pteraster.*

Verrill (1894, p. 277) says: "This species not only differs from other known forms in having six rays, but appears to be peculiar in the presence of naked interradial grooves and genital slits. This last character may be sufficient to warrant its separation as a distinct subgenus (*Temnaster* Verrill) or even as a genus. It differs from our other species also in having fewer and stouter spines in the ventral combs; in the broader and flatter ventral surface of the shorter rays; in the much thicker skin of the ventral combs, and in the less evident comb of spines along the margins of the rays. The dorsal membrane is also firmer and not at all granular; the spinules over its surface are much more numerous, and the pores between them are smaller and more numerous."

The character of the adambulacral armature, the dimensions, the width of the actinolateral membrane, and lateral fringe, the thickness of the supradorsal membrane, the number of paxillar spines and spiracula are, as Verrill intended to show, merely specific and not generic features. The generic characters mentioned in the first sentence are: Six rays and interradial slits. The latter are temporary openings for the escape of the young, not permanent apertures. Furthermore, as probably holds true also for other species of *Pteraster* the slits may occur elsewhere in the supradorsal membrane. In small specimens there is not even a smooth interradial groove. We are really thrown back upon the number of rays which is not invariably six, but is sometimes seven, eight, or nine. While it may be convenient to segregate *Pteraster obscurus* in a subgenus *Hexaster* I do not think the number of rays should constitute a generic division, any more than in *Anseropoda*, *Pedicellaster, Leptasterias, Asterias,* or in other groups having constantly six-rayed species. In the absence of any structural features separating this form from *Pteraster,* I have classified the species under that genus.

Since the above was written Professor Verrill has described *Pteraster octaster* from Bering Island.[a] I have listed two specimens with eight rays from Bering Island, evidently a part of the same lot collected by Doctor Stejneger. These are in rather poor condition as regards the actinal surface, but a small specimen from station 3557 is in a perfect state of preservation.

I have gone over these specimens again and have compared them with seven-rayed and six-rayed examples. The result is that I am unable to find sufficient structural difference to warrant the segregation of the eight-rayed form as a separate species. The highly characteristic paxillæ are the same in the eight as in the six- and seven-rayed specimens, showing no more variation than can be found in several six-rayed examples. So also with the actinal surface. In eight-rayed specimens the interradial areas are naturally smaller than in examples with six rays, but not much smaller. The structure and spinulation of the mouth and adambulacral plates is the same.

Reference has already been made to the fact that the young of the large seven-rayed specimen have six rays. I opened the nidamental cavity of the two eight-rayed Bering Island examples and found six young, one of which has nine rays, three have eight rays, and two have seven rays, all three kinds being found in the same individual. This is enough to show that there is no stability in the number of rays. This circumstance coupled with the structural similarity of six-, seven-, and eight-rayed specimens has led me to place *Pteraster octaster* as a synonym of *obscurus.*

It is of interest to note that Professor Verrill described the new form as a *Pteraster* and not as *Hexaster* (*Temnaster* Verrill).

Two specimens were opened, but were too badly macerated to determine the internal structure in detail. The anatomy seems to be essentially the same as in typical *Pteraster.*

In "Some Japanese and East Indian Echinoderms"[b] Dr. Hubert Lyman Clark has published a very useful key to the species of *Pteraster,* upon which the following key is based. *Pt. aporus* has been omitted, and a number of changes, other than the introduction of new species, instituted. As the two keys differ in some details, both may be used to advantage for the identification of specimens. The key has been brought up to January, 1910.

KEY TO THE KNOWN SPECIES OF PTERASTER.

a^1. Form more or less stellate; R greater than 1.8 r, usually 2 to 3.5 r.
  b^1. A stout spine (suboral) present on surface of each mouth plate.
    c^1. Tube feet in two series; supradorsal membrane with spiny deposits[c] and not conspicuously reticulated.
      d^1. Ambulacral comb with more than five spines.
        e^1. Stalk of paxilla short, not much higher than thick; spinelets much longer, three to five; supradorsal membrane crowded with deposits; oral spines six to eight. .*militaris,* Müller.

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[a] Amer. Journ. Sci., July, 1909, p. 61, fig. 1.

[b] Bull. Mus. Comp. Zoöl., vol. 51, No. 11, April, 1908, p. 286.

[c] Not mentioned in *caribbæus* and *affinis;* probably present.

KEY TO THE KNOWN SPECIES OF PTERASTER—continued

e^2. Stalk of paxilla high and slender with six or seven spines, oral spines five or six. .... *caribbæus* Perrier.

d^2. Ambulacral comb with three to five spines.

e^1. Oral spine very large and three-edged; paxilla stalk high with six spines; adambulacral spines five........ *trigonodon* Fisher.

e^2. Oral spine not three-edged.

f^1. Oral spines six; supradorsal membrane thick and smooth with spiny calcareous bodies; paxilla stalk low; three to five adambulacral spines........ *lebruni* Perrier.

f^2. Oral spines four; supradorsal membrane thin; paxillæ with numerous (five to ten) spinelets; four adambulacral spines........ *affinis* Smith.

c^2. Tube feet in two series; supradorsal membrane thin, delicate, reticulated, and without deposits; oral spines two, independently webbed........ *gracilis* Clark.

c^3. Tube feet in four series, at least proximally; supradorsal membrane either without deposits or with a very few simple rods.

d^1. Adambulacral comb of three or four spines; oral spines four; no small lateral pockets back of aperture papilla; no deposits in supradorsal membrane; spiracula........ *jordani* Fisher.

d^2. Adambulacral comb of five spines proximally; oral spines five; small shallow pockets just back of aperture papillæ; supradorsal membrane with a few scattered simple rods, spiracula absent........ *marsippus* Fisher.

b^2. No suboral spine present.

c^1. Adambulacral spines five, in curved series; oral spines five........ *personatus* Sladen.

c^2. Adambulacral spines four, in straight series; oral spines six........ *sordidus* Perrier.

c^3. Adambulacral spines six or five, oral spines six; fifteen to twenty spinelets to paxilla, compact........ *reductus*[a] Kœhler.

a^2. Rays very short; R less than 1.8 r, usually 1.3 to 1.7 r; form often more or less pentagonal (that is in pentamerous species); suboral spine present.

b^1. Rays regularly five.

c^1. Adambulacral armature five to seven spines.

d^1. Oral spines united by membrane.

e^1. Oral spines five to seven, the two series joined by a single continuous membrane; abactinal surface swollen and sometimes more or less warty in adult.

f^1. Membranes thick and fleshy; size large; supradorsal membrane more or less reticulated, or else creased by fine furrows into which open the spiracula; R=1.4 to 1.8 r.

g^1. With well-developed rays; R=1.6 to 1.8 r; with reticulated membrane... *tesselatus* Ives.

g^2. Arcuately pentagonal in form; R=1.44 r. No evident reticulations.... *arcuatus* Fisher

f^2. Membranes not especially thick, but rather thin, often translucent, R=1.3 r.

g^1. Paxillæ with high pedicel and five to fifteen spines; suboral spine slender cylindrical; muscle bands connecting tips of paxillar spines; aperture slits small; oral spines six to seven; no deposits in supradorsal membrane; lateral fringe not defining ambitus........ *pulvillus* Sars.

g^2. Paxillæ low, with low pedicel and five to seven short spines; suboral spine with three sharp edges; no muscle bands connecting tips of paxillar spines; aperture slits unusually large; oral spines five; in supradorsal membrane, deposits in the form of branched rods; lateral fringe defining ambitus........ *temnochiton* Fisher.

e^2. Oral spines three, the series independently webbed; abactinal surface not much elevated and not at all warty; adambulacral spines, six........ *multispinus* Clark.

d^2. Oral spines free, not webbed.

e^1. Actinolateral membrane defining ambitus; first two (innermost) oral spines not flattened and truncate; actinolateral spines much longer at middle of ray than near tip.

f^1. R=1.7 r; suboral spine very heavy club-shaped, with an incipient three-sided point; supradorsal membrane with reticulations, oral spines five to seven; spiracles not exceedingly numerous........ *reticulatus* Fisher.

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[a] Very close to *personatus;* according to Kœhler, distinguished by its constantly smaller size, compact paxillæ, longer adambulacral and oral spines, with one more spine in each series.

KEY TO THE KNOWN SPECIES OF PTERASTER—continued.

f^2. R=1.4 r; suboral spines very slender and long, without trace of three-sided tip; no heavy supradorsal reticulations; oral spines six; spiracles exceedingly numerous. *coscinopeplus* Fisher.

e^2. Actinolateral membrane very narrow, not defining ambitus; actinolateral spines of approximately equal length except at very tip of ray; no supradorsal reticulations; first two oral spines very flat and truncate........ *obesus* Clark.

c^2. Adambulacral armature three to five spines.

d^1. Oral spines three to five, not united by a web.

e^1. Adambulacral spines short, scarcely projecting beyond web........ *stellifer* Sladen.

e^2. Adambulacral spines slender, projecting far beyond web........ *danæ* Verrill.

d^2. Oral spines united wholly, or in groups, by a web.

e^1. Oral spines of each mouth angle all united by a common membrane.

f^1. Actinolateral membrane fairly broad, or very broad, the lateral fringe defining ambitus.

g^1. Suboral spine three-edged, sharp; apertures unusually large; adambulacral spines five; oral spines five; R=1.3+r........ *temnochiton* Fisher.

g^2. Suboral spine not three-edged; apertures not unusually large; adambulacral spines three to five.

h^1. Adambulacral spines usually three, sometimes four, short, scarcely projecting beyond web; R=1.4+r........ *rugatus* Sladen.

h^2. Adambulacral spines three to five, usually four, projecting far beyond web.

i^1. R=1.75 r±; dorsal membrane thin, evidently reticulated.. *semireticulatus* Sladen.

i^2. R=1.4 r±; dorsal membrane thick, not at all reticulate........ *ingolfi* Perrier.

f^2. Actinolateral membrane narrow not defining ambitus; actinolateral spines short, little longer than outermost adambulacral spine; oral spines six; adambulacral spines five; spiracula very abundant; R=1.6 r........ *multiporus* Clark.

e^2. Oral spines webbed so as to form at each mouth angle four groups; two innermost spines long, four lateral short, each group united by web; adambulacral spines usually four; no spiracula........ *alveolatus* Perrier.

b^2. Rays regularly six, seven, eight, or nine, usually six; supradorsal membrane thick; spiracula numerous; abactinal surface spiny; actinolateral membrane and furrow webs thick; adambulacral spines four to seven; oral spines five or six, completely webbed; R=1.4 to 1.65 r. *obscurus* Perrier.

Genus DIPLOPTERASTER Verrill.

Diplopteraster VERRILL, Amer. Journ. Sci., vol. 20, 1880, p. 400. Type, *Pteraster multipes* Sars.
Retaster SLADEN, part, *Challenger* Asteroidea, 1889, p. 477.

Diagnosis.—Pterasteridæ agreeing with *Retaster* in having a strongly reticulated supradorsal membrane, but differing in having two kinds of adambulacral plates, less prominent alternating with more prominent, and correlated with them, two sorts of furrow combs, one larger and set farther into furrow, and having sometimes one spine more, the other set back slightly; tube feet in four rows; mouth spines all webbed together; actinolateral membrane (in contrast to *Retaster*) very broad, and fleshy in fully adult specimens. Madreporic body not bearing a tuft of spines on its summit.[a]

Three closely related species are known: besides the type, *Diplopteraster verrucosus* (Sladen), Atlantic entrance to Strait of Magellan, and *D. peregrinator* (Sladen), off Cumberland Bay, Kerguelen Island.

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[a] I am not certain as to the value of this character. *Retaster* and some, but apparently not all, species of *Pteraster* have a paxilla on the madreporic body.

KEY TO THE KNOWN SPECIES OF DIPLOPTERASTER.

a^1. Central spine of pseudopaxillæ projecting far beyond the others, giving a very bristling or spiny appearance to supradorsal membrane; prominent furrow combs with four or five spines; nonprominent with three to five.
  b^1. Pseudopaxillæ with eight to ten spines; triangular meshes of supradorsal reticulum with eight to twenty spiracula; usually one spine less in the nonprominent furrow comb; longest adambulacral spines and sacculus at least three times, sometimes four times, as long as base line of prominent combs..*multipes* (Sars), p. 371.
  b^2. Pseudopaxillæ with fifteen spines; triangular meshes with four or five spiracula; both kinds of furrow combs with five spines; longest adambulacral spines and sacculus less than twice as long as the base line of the prominent combs (figure)..............................*verrucosus* (Sladen).
a^2. Central spine of pseudopaxillæ not protruding far beyond the rest and supradorsal membrane not conspicuously spiny; five to ten paxillar spinelets; two or three spiracula to a mesh; prominent furrow combs with seven or eight spines; alternate combs with five..........*peregrinator* (Sladen).

Remarks.—The species described by Sladen are evidently very close to *multipes*. It is somewhat remarkable that no mention is made of this similarity. The differences outlined in the above synopsis may break down somewhat when an adequate series of the southern forms is examined. It will not be surprising if *D. verrucosus* becomes a synonym of *multipes*, for the two are much alike. However, if the characters outlined by Sladen hold constant, they can be kept distinct. Sladen's specimens (number not designated) came from a single station, at the Atlantic entrance to the Strait of Magellan, 55 fathoms, sand.

As to the validity of this genus, opinions will, of course, differ. The characters mentioned in the diagnosis are as important, surely, as those which serve to separate *Retaster* from *Pteraster*. In fact, it is much easier to draw the line between *Diplopteraster* and *Retaster*, than between the latter and *Pteraster*.

DIPLOPTERASTER MULTIPES (Sars).

Pl. 107, figs. 1, 2.

Pteraster multipes M. SARS, Forh. Vid. Selsk. Christiania, 1865, p. 200; Fauna Littoralis Norvegiæ, pt. 3, 1877, p. 65, pl. 8, figs. 1–17.
Diplopteraster multipes VERRILL, Amer. Journ. Sci., vol. 20, 1880, p. 400.
Retaster multipes SLADEN, *Challenger* Asteroidea, 1889, p. 477.

Diagnosis.—Rays five, rarely six; general form stellato-pentagonal or very broadly stellate, with depressed disk; actinolateral membrane broad and fleshy with free lateral border defining the ambitus; ambulacra very wide with large tube feet in four rows; $R=92$ mm., $r=71$ mm., $R=1.3\pm r$; a small specimen, $R=1.52\ r$. Supradorsal membrane tough, bristling with the prominent central spines of each paxilla; paxillæ with long pedicels surmounted by a prominent stout central spine and seven to nine slender shorter radiating peripheral spines, the tip of each being joined to that of central spine, and also together, by a muscular band, the thinner membrane between being pierced by about eight to twenty spiracula, the spiracular areas thus are radially disposed about the prominent central spine of each paxilla; osculum large. Adambulacral plates with two kinds of combs, one projecting farther into furrow than the other; prominent combs with four or five webbed spines; nonprominent with three or four; web prolonged beyond tips of longer spines as a long flap or sacculus. Oral spines four or five (rarely six on one side), slender, the two series united by a continuous membrane; suboral spine as slender or slenderer than innermost oral and usually slightly shorter.

Notes on Pacific specimens.—Most of the specimens are very large, the spines being heavy and the integumentary developments of the actinal surface thick and tough. In the specimen from off San Diego the spines are more delicate and the whole animal more lax.

The specimens agree very well with Atlantic examples, with which comparison has been made. Judging by the single Californian example from station 4353, and one Japanese specimen, 475 fathoms, Suruga Gulf, variation has been toward a slight decrease in the number of spines in the former, especially on the nonprominent adambulacral plates, and a slight increase in the latter (seven spines in the prominent combs, six in the nonprominent). In the Japanese example there are about nine spines to the paxillæ, which have very long pedicels relatively slightly longer than in Atlantic examples.

All the specimens are bristling with the stout central paxillar spines which push up the membrane and occasionally protrude through. In small examples the spiracles are disposed in seven regular series radiating from the central spine, but later the arrangement becomes irregular (except in the Japanese specimen where the series are fairly straight).

The "prominent" adambulacral combs usually have the innermost, or furrow, spine long, while the "nonprominent" plate has a very small furrow spine, though sometimes it is long. Always, however, the comb is set back. The nonprominent plate may have as many spines as the prominent, though in that case the furrow spine is usually small; there is ordinarily one spine less on the nonprominent plate. In a large specimen, beginning with a prominent plate at base of furrow, the number of spines run as follows, the nonprominent being marked by a star: 5, 5*, 6, 4*, 5, 4*, 5, 4*, 4, 4*, 5, 4*, 5, 4*, 4, etc. The innermost spine, if fully developed, is the longest, the rest decreasing slightly in length, outward. Sometimes the second is the longest, or all are very nearly the same length, or at base of ray the spines are graduated in length from the innermost outward. The saccular prolongations of the web at tip of spines vary in length, being usually nearly as long as the spine itself. In small specimens, however, they are not prominent. The first ambulacral web is continued across to meet its fellow, just back of the mouth plates.

The actinolateral membrane is thick and fleshy in the large examples, in some of which the free border forms a nearly straight edge to the side of the body, but is arched inward in others. Small specimens have the membrane thinner, so that the spines show through. The ambulacral webs are continued out upon the membrane for a short and variable distance, farthest, apparently, in the very old specimens.

The madreporic body is large, very convex, marked by coarse radiating furrows. There is no tuft of spinelets from the summit as in *Pteraster tesselatus*.

One of the specimens has six rays, but is otherwise like the rest.

Type-locality.—Dröbak, Norway; 60 fathoms.

Distribution.—Probably circumpolar; known from the north Atlantic, on the west side, from 35° to 45° north latitude (Verrill) and on the east side from Norway and Barents Sea; in the north Pacific, from San Diego, California, and Suruga Gulf, Japan, north to Bering Sea. Vertical distribution: in the Atlantic 50 to about 580 fathoms; in the Pacific, 81 to 640 fathoms.

Specimens examined.—Eleven, from the following localities:

Specimens of Diplopteraster multipes examined.

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms.			
3224......	Near Unalaska, Alaska..........	121	black sand, gravel..	1	U. S. Nat. Mus.
3226......	North of Unalaska..	128	mud, sand, shells.	2	Do.
3331......	.....do......	350	mud...	1	Do.
3500[a].....	South of Pribilof Islands......	121	fine gray sand, gravel....	2	Do.
3602......	West of Pribilof Islands...	81	green mud, sand.	2	Do.
4235......	Near Yes Bay, Behm Canal, Alaska..	181	gray mud..	1	*Albatross*, 1903.
4353......	Off San Diego, California.....	628-640	green mud......	1	*Albatross*, 1904.
4784......	Near Attu Island, Aleutians.........	135	coarse pebbles...	1	*Albatross*, 1906.

[a] Bottle broken by earthquake, 1906; some doubt as to label; probably this station.

Remarks.—The differences between this species and the two others of the genus are noted in the foregoing key.

The explorations of the *Albatross* in the North Pacific have more than doubled the known range of this species, which was heretofore recorded only from the North Atlantic. Some of the Bering Sea examples are very large (R=over 90 mm.), and therefore show a tendency shared by other North Atlantic forms found in this general region; as, for example, *Henricia sanguinolenta*, *Pteraster militaris*, *Pseudarchaster parelii*. These specimens, if not the largest known Pterasteridæ, are at any rate the fleshiest and heaviest.

Genus HYMENASTER Wyville Thomson.

Hymenaster Wyville Thomson, The Depths of the Sea, 1873, p. 120. Type, *H. pellucidus* Wyville Thomson.

Diagnosis.—Pterasteridæ in which the armature of the adambulacral plates does not form transverse webbed combs, the spinelets being independent; nidamental cavity spacious; spinelets of paxillæ not protruding through, but supporting the membrane, which contains numerous muscle fibers and few to many spiracula.

KEY TO THE SPECIES OF HYMENASTER HEREIN DESCRIBED.

a^1. Adambulacral armature consisting of one spinelet; size very large; paxillæ forming special raised areas; spiracula small in definite circumscribed areas ....*kœhleri*, p. 373.

a^2. Adambulacral armature consisting of more than one spinelet; spiracula not in definite circumscribed areas.

  b^1. Median radial paxillæ very much reduced in size; with one to three basal lobes; five rows of paxillæ on ray; adambulacral spinelets, two or three ....*perissonotus*, p. 376.

  b^2. Median radial paxillæ not greatly reduced in size, with four basal lobes; nine rows of paxillæ along ray; very numerous small spiracula; adambulacral spinelets, four or five. *quadrispinosus*, p. 380.

HYMENASTER KŒHLERI Fisher.

Pl. 108, fig. 1; pl. 117, fig. 4

Hymenaster kœhleri Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 170.

Diagnosis.—Very near to *H. nobilis* Wyville Thomson,[a] which it resembles in general appearance, number, and arrangement of paxillar spines and adambulacral

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[a] For figures and description, Sladen 1889, p. 495, pl. 87, figs. 1-3.

spines, but from which it differs in the following details: spiracula in very definite circumscribed areas, not confluent between the paxillar crowns; the regular transverse spiracular areas of interbrachial web of *nobilis* absent or only indicated irregularly toward ends of rays; replaced proximally by detached scattered small spiracular areas; furrow spinelet much shorter than segmental papilla; oral spines short (one-half length of interradial suture, or less).

Description.—Size large; general form stellato-pentagonal; R= about 100 mm., r= about 70 mm., R= about 1.4 r. The second specimen has more evident rays and deeper interbrachial arcs; R=82 mm., r=45 to 52 mm.; R varies from 1.8 to 1.5 r. The interbrachial webs well shown in Sladen's figure of *nobilis*, and which leave the paxillar area somewhat raised, and sharply differentiated in both *nobilis* and the present form, are very muscular and contractile, hence in preservation are likely to differ widely in extent. *H. kœhleri* has deeper interbrachial arcs than *nobilis*, but this may be due to preservation, as the two specimens differ so much. Abactinal surface very similar to that of *nobilis*, the supradorsal membrane fairly thick, and the less elevated interbrachial webs very fleshy. Paxillæ with three rather long, slender spines (occasionally four), which raise the membrane exactly as described by Sladen for *nobilis;* moreover the spinelets are oriented the same way; two usually aboral to the third, which is opposite to their interspace. There are six rows of paxillæ along each ray as in *nobilis*. Spiracula numerous and small, in very definite irregular areas surrounded by a low fold of the integument, or the whole area may be sunken; ten to one hundred spiracula to an area. On the lateral fringe or web are scattered spiracula areas, some of which are elongated and are homologous to the regular and more numerous parallel areas in *H. nobilis*. These elongated areas are more evident in the large specimens and occur beyond the middle of the ray and are not so long as in *nobilis*. Proximally the areas of the web are small and without order. From Sladen's description and figure of *nobilis* the spiracula of the paxillar region are not confined to sharply defined circumscribed areas, as in *kœhleri*, but are confluent among the paxillæ. Osculum large, similar to that of *nobilis*, the fan-like valves being a little higher and slightly more acute; spines twelve. The depression just back of the fans contains numerous spiracula, which also occur in the web between the five fans; they also form linear areas between the spines of the fans, but are variable in this respect.

Adambulacral plates with an angular furrow margin bearing a single short spinelet (2 to 2.5 mm.) invested in membrane, which is prolonged beyond the tip (as in *nobilis*) one to three times the length of the spine. Aperture papillæ relatively somewhat larger than in *nobilis*, ovate, with a slight sacculus at tip (length, 3.5 mm., width 2 to 3 mm.). Tube feet large, in two rows; sucking disk small.

Actinolateral membrane similar to that of *nobilis*, thick and fleshy, traversed on actinal surface by parallel grooves (between the actinolateral spines). In the type these reach to the interradial line proximally but leave a smooth triangular area in the interradius near the margin. The apex of this triangle is at the point where the proximal actinolateral spines of neighboring rays meet in interradial lines. Near margin the grooves are roughly parallel with border of disk, but, as just mentioned, do not reach to the interradial line. Spines buried beneath the fleshy membrane, the ninth the longest; adorally from that point the tips of the spines nearly or quite touch in the interradial line, but distad they are widely separated. In the interradial angle near border, crisscrossing muscle bands are very evident on actinal surface, those nearest the margin being largest. In the cotype the grooves are not nearly so conspicuous as in the type and the actinolateral spines are easily seen through the membrane, which is not the case in the type. From the first to the ninth or tenth the actinolateral spines gradually become longer; from about the tenth to twentieth they are subequal, being between one-fourth and one-fifth R in length; from the twentieth to the fortieth they decrease rapidly in length, those at tip of ray being exceedingly short.

Mouth plates as shown in figure, with a broad, free margin. Marginal spines of type, three or four, short (one-half as long as median suture or less), the inner being spaced a little from the other three. Cotype with two or three marginal spines. Suboral spine one, not far from median suture and slightly more than one-third the distance from inner marginal spine to outer end of median suture. Spine short and thick. (See Pl. 117, fig. 4.)

Color in alcohol, bleached pink or brownish purple above, dull reddish purple below.

Anatomical notes.—Nidamental cavity large, extending beyond tips of actinolateral spines. Papulæ very large and saccular, one to each paxilla, except the primary radials, and rising higher than the pedicels, to which they are attached. They sometimes are filled with folds from hepatic cœca. Base of paxillæ with three long, slender processes; the adradial paxillæ with two longer processes directed toward margin and a short mesially directed arm. The abactinal skeleton is very open and loose. There is no radial series of poxillæ, and the adradials do not join across the median radial area. The periproct membrane between the primary radial (or ocular) paxillæ and anal aperture contains thin, large, subcircular or polygonal, closely juxtaposed plates in mosaic. There are about two concentric circles of them. Intestinal cœcum a rather spacious, simple, or short-pocketed sac between the dorsal stomach and anal aperture. It looks like a dilation of the intestine. The stomach and hepatic cœca essentially as in *Pteraster*. First ambulacral ossicle, as in *Pteraster*, greatly enlarged for the insertion of muscles controlling stomach. Ampullæ double; tube feet, with a small button on the end; apparently no Polian vesicles. Madreporic body large, convex, with meandering striæ. Gonads interradial, attached to the membranous interradial septum.

Type.—Cat. No. 27795, U.S.N.M.

Type-locality.—*Albatross* station 3603, Bering Sea, between Pribilof Islands and Unimak Island (Aleutians), 1,771 fathoms, blue ooze; two specimens.

Distribution.—Known only from type-locality.

Remarks.—This large species is allied to *H. nobilis*, from which it differs, as detailed in the foregoing description. It differs from *H. carnosus* Sladen, as does *H. nobilis*, in having one adambulacral spinelet and specialized paxillar areas. The same differences separate it from *H. pentagonalis* Fisher. Both of these species have the fleshy habit of *kuhleri*. *H. violaceus* Ludwig (southeast of Acapulco, Mexico, 1,879 fathoms), which also has one adambulacral spine, differs in having a central and about six peripheral paxillar spinelets one-third as long as the central. The abactinal surface is like *H. carnosus* in the form and arrangement of the paxillar spines; therefore quite different from *kœhleri*. There are seven irregular longitudinal rows of these points, while in *kœhleri* (as in *nobilis*) there are six regular series, a median radial being wanting. In *violaceus* the furrow spinelet (without the membrane) is as long or a trifle longer than the segmental papilla, while in *kœhleri* the latter is one and one-half times as long as the furrow spinelet.

Hymenaster nobilis was taken at *Challenger* station 158, south of Australia, 1,099 miles southwest of Cape Otway, 1,800 fathoms globigerina ooze, and by the *Investigator* in the Bay of Bengal, 1,748 fathoms. It is of interest to find such a closely related form in the extreme north Pacific.

I take pleasure in dedicating this handsome species to Dr. R. Kœhler, of the University of Lyon.

HYMENASTER PERISSONOTUS Fisher.

Pl. 109, figs. 1, 2; pl. 115, figs. 1, 1*a–e;* pl. 117, figs. 3, 3*a*.

Hymenaster perissonotus Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 170.

Diagnosis.—General form depressed, nearly pentagonal, with subplane abactinal surface and extensive interradial webs supported by actinolateral spines, which are conspicuously heavier beyond middle of ray. Paxillar area not conspicuously raised. Marginal paxillæ conspicuously larger than the three series of abactinal, the radial being very short and, distally, rudimentary. Supradorsal membrane close to abactinal wall along median radial area. Spiracula large, scattered, fairly, but not very numerous; membrane with very numerous crisscrossing muscle fibers, which radiate from tips of delicate paxilla spinelets, usually three or four of these to a paxilla; points of spinelets uniformly spaced on supradorsal membrane, and individual paxillæ not distinguishable. Adambulacral spinelets two, or less often three; oral spines five or six, rarely seven, suboral spines one or two; aperture papillæ large, ovate.

Description.—General form pentagonal and very flat, the sides of the pentagon being nearly straight, except that the tips of the rays are slightly prolonged; $R = 70$ mm., $r = 50$ mm., $R = 1.4\,r$. Lateral web extending beyond paxillæ and supported by the stout actinolateral spines. There is only a very narrow interradial strip free from the spines, of which those near middle of ray are conspicuously stouter than the proximal ones. Supradorsal membrane thin, and when the epidermis is rubbed (as it usually is), very translucent, showing thread-like slender muscle bands running between the tips of the paxillar spines. These fibers are not of uniform thickness. They crisscross in every direction and branch, and are more numerous in some specimens than in others. Paxillar areas broadly petaloid, but not raised, the abactinal surface being as near flat as possible. Adjacent areas are confluent along the adcentral half of r. Paxillar spines forming rather abrupt low uniformly spaced protuberances over the paxillar area, individual paxillæ being not at all discernible. Spiracula large for this genus, larger and fewer than in *quadrispinosus*, and scattered without order. The larger specimens have more than the smaller. A few occur on the interradial area outside the paxillar region on finger-like outpouchings of the nidamental cavity.

The paxillæ of the median radial region are very small, with short spinelets and pedicels beyond the proximal third of R, but on either side they rapidly increase in length, the lateralmost or marginal being the largest. This striking discrepancy in size results in the nidamental cavity being almost entirely interradial, as the supradorsal membrane rests upon the ambulacral ridge beyond the proximal third of R. The radial paxillæ at about the middle of R measure 2 mm. or less in height (the pedicel being too short to measure). A corresponding inferomarginal paxilla measures: pedicel, 4 mm., + spines, 6 mm. (station 2919). On the outer third of the radial line the scattered paxillæ are rudimentary and simply anchor the supradorsal membrane to the very thin abactinal integument. Small paxillæ have three very slender spinelets; the larger adradial, three; and the marginal, three to five spines, all very slender. Osculum large, the valves with about eighteen spines on the side toward aperture and about five short ones back of these. The lateral spinelets of the comb rapidly become smaller. (Pl. 115, figs. 1*a*, 1*b*.)

The abactinal skeleton is exceedingly weak, the processes forming the base of the paxillæ being unusually long and slender. The inferomarginal plates have four, the superomarginal three proximally, two distally, and the abactinal one to three. The interspaces are unusually large, especially along the medioradial area. The two adoral processes of the inferomarginal paxillæ are longer than the two aboral, and the inferior branch of the superomarginal plates is stouter and a trifle longer than the one or two processes directed mesially. The true abactinal plates have almost thread-like processes and are in three irregular series, a radial and on either side an adradial, the latter with usually three processes proximally and two on outer part of ray. Proximally the processes of the plates touch, but distally the radial series of rudimentary paxillæ has often only a single long, slender process, which may not be in connection with any other plate. The inconstant number of lobes results in an irregular mesh, the integument of which on the proximal part of the ray contains irregular, elongated scattered thin plates, consisting of a single layer of calcareous reticulum. The membrane between the primary radial or oscular valve plates and anal aperture contains numerous large, thin subcircular or elongated plates. (Pl. 115, figs. 1, 1*c*, 1*d*, 1*e*.)

Papulæ large on the proximal part of the ray, small and confined to the lateral parts of ray beyond the middle of R. The distal fourth of R is without papulæ. The papulæ are saccular, and the surface is subdivided into many small outpocketings, giving the appearance of a miniature cauliflower. The papulæ stand alone (not attached to paxillæ), and the proximal are often filled with the hepatic cæca.

Madreporic body very large and prominent, being about as high as wide, subglobose, and marked with fine branching centrifugal striæ. It is situated not interradially, but next to a primary radial or oscular paxilla. The actual disk is so small the plate has become pushed to one side.

Actual disk very small; R = 85 mm., actual r = 10 to 14 mm.; diameter of ray at base about 15 mm.; diameter of madreporic body 8 to 10 mm. Thus it is evident the actinolateral membrane is very wide and the interradial cavities spacious. (See dimensions above.)

Adambulacral furrows fairly wide; tube feet in two rows, with small disks or buttons at the tip, except near the tip of ray where the feet are pointed. Armature consists of typically two (but some plates with three) slender furrow spinelets in a longitudinal series, the adoral slightly the longer (4.5 mm.) and about as long as the distance between the base of two adoral spinelets of two plates. The spinelets have a flange of tissue broadening distally and continued beyond the tip for a short distance. Aperture papilla situated just back of the aboral furrow spinelet, or the interval between the two spinelets. It is very broad, ovate or obovate, and with the fleshy part is about as long as the calcareous portion of the longer furrow spinelet. The calcareous support of the papilla is variable, but is either ovate with a blunt or truncate tip, or is even broader than long with a truncate ragged end. A fleshy tip often extends into the aperture, plugging it up, but is not superficially apparent. It is really a short sacculus and varies in size, apparently never long.

Free margin of each mouth plate nearly as long as interradial diameter of plate, the combined plates, therefore, presenting a broad margin to actinostome. Marginal spinelets slender, subequal, five or six, rarely seven, to each plate, similar to the adambulacral spinelets, and nearly evenly spaced. Suboral spinelets two, somewhat thicker and a trifle shorter (about one-half length of interradial diameter of plate). The inner one sometimes moves to the margin and becomes the innermost marginal spine. When there are two suborals there are four or five marginals.

Actinolateral spines gradually increasing in length and thickness along ray, the twelfth to eighteenth (about) being longest and heaviest. None of the spines quite meet, across the interradial space, those of adjacent ray. From about the seventeenth or eighteenth the spines become rapidly shorter and the tips end at the free border of the web instead of being embedded in the web. Most of the larger spines are broken (some apparently before the death of the animal), forming a sort of joint. Just above the articulating facet the base of each spine has an abrupt expansion on either side. The membrane is thin, so that the spines are conspicuous. The interradial portion between the tips of two series of spines is muscular.

Color in alcohol, bleached yellowish.

Variations.—The outward appearance of all the specimens is essentially the same. Those from very deep water (station 3307) apparently have a more translucent membrane, but this is in a large measure due to the epidermis having sloughed off either from long immersion in very weak alcohol or from scouring of mud and fine sand in the dredge. In such examples the muscle fibers are much more conspicuous than in normal specimens. However, the supradorsal membrane is weaker in deep-water specimens. There is variation in the number of muscle fibers. Mention has already been made that a minority of the adambulacral plates may have three spines; the number of such plates is highly variable, and they occur in both northern and southern and in the shallower and deeper water specimens.

The contour of the disk varies. Sometimes the long actinolateral spines cause the interradial web to extend outward, forming an interradial corner so that the creature apparently has ten angles and ten sides instead of five.

A very remarkable specimen from station 2859 off Prince of Wales Island, Alaska, 1,569 fathoms, was taken along with *H. quadrispinosus*. It exhibits all the characters of *perissonotus* except that the adambulacral plates have an oblique transverse row of five flattened spinelets, the inner the shortest, the outer the longest, the rest graduated between. Sometimes the next to outer is longest. The aperture papillæ are larger as in *perissonotus*. The specimen has R. 72 mm. and the characters of paxillæ, abactinal plates, supradorsal membrane, spiracula, actinolateral spines and membrane are absolutely typical of *perissonotus*. As this aberrant specimen was taken with *quadrispinosus*, it is possible that it is a hybrid between that species and *perissonotus*, although no typical examples of the latter were taken at station 2859.

A six-rayed specimen is present in the lot from station 3074.

Type.—Cat. No. 27796, U.S.N.M.

Type-locality.—*Albatross* station 2919, off Cortes Bank, west of San Diego, California, 984 fathoms, gray mud.

Distribution.—From San Diego, California, to Bering Sea, 225 to 1,771 fathoms.

Specimens examined. Seventy-eight, from the following localities:

Specimens of Hymenaster perissonotus examined

Station.	Locality.	Depth.	Nature of bottom.	Number	Collection.
		Fathoms.			
2919	Off Cortes Bank, west of San Diego, California.	984	gray mud	6	U. S. Nat. Mus.
3074	Off Sea Lion Rock, Washington.	877	green mud	10	Do.
3075	do	859	do	24	Do.
3227	Bering Sea (north of Unalaska)	225	do	8	Do.
3307	Bering Sea (northwest of Umnak Island).	1,033	green ooze	7	Do.
3342 [a]	Off Queen Charlotte Islands, British Columbia.	1,588	gray ooze	1	Do.
3346	Off Tillamook Bay, Oregon	786	green mud	11	Do.
3601 [a]	Bering Sea, between Pribilof Islands and Unalaska.	1,044	green mud	1	Do.
3603	Bering Sea (east of Pribilof Islands)	1,771	blue ooze	1	Do.
	No locality [b]			9	Do.

[a] Bottles broken during earthquake 1906, but label probably correct.

[b] Bottle broken during earthquake 1906.

Remarks.—This species falls under section B, sub-b, *b*, of Sladen's *Challenger* Synopsis, although it does not quite agree because there may be three adambulacral spinelets on some plates, and only three paxillar spinelets. Of the four species mentioned, *perissonotus* most resembles *vicarius*, from off Chile, 1,375 fathoms. It differs from *glaucus* in lacking the conspicuously defined radial areas raised in relief above the rest of the abactinal surface. From *vicarius*, *perissonotus* differs in having the median radial paxillæ very much smaller than the lateral, in having three or four, not four, five, or six paxillar spinelets, in having a more pentagonal contour, with the actinolateral spines increasing in thickness at about the middle of ray, and in having sometimes three, as well as two, adambulacral spinelets. From *pellucidus*, *perissonotus* differs in respect to the size of the paxillæ, and in having fewer paxilla spinelets, more numerous muscles in the supradorsal membrane, a thicker less transparent membrane, and more numerous and large spiracula. *H. pellucidus* has four conspicuous rows of paxillæ along each ray. *H. infernalis* has a stellate contour, eight to ten paxillar spinelets, and none of the more salient characteristics of *H. perissonotus*. Among the species with three adambulacral spinelets, figured by Sladen, *perissonotus* resembles most *H. membranaceus* Wyville Thomson, from which it differs in having reduced median radial paxillæ (not mentioned, however, in Sladen's description), more often two than three adambulacral spinelets, more numerous spiracula, and differently formed mouth spines.

Of the species described by Ludwig from the Panama-Galapagos region, the only one with which the present needs comparison is *H. gracilis*, from which *perissonotus* differs in the great disparity in size between radial and marginal paxillæ, in having three or four, rarely five, paxilla spinelets (not as many as seven), in having the abactinal plates (radial and adradial) with only one to three basal processes, not four. The abactinal plates of *gracilis* are regularly disposed forming quadrate meshes, and the superomarginal plates have five processes, not two or three as in *perissonotus*. The abactinal integument of *perissonotus* contains calcareous platelets in the meshes of the skeleton; *gracilis* has none. *Gracilis* has three or four oral spinelets, *perissonotus* has five to seven. The madreporic body of *gracilis* is small, that of *perissonotus* very large.

This species is readily distinguished from others described in this report by the remarkable structure of the abactinal paxillæ which with their supporting base are greatly reduced on the radial areas, the marginal paxillæ being very much larger. The nidamental cavity is chiefly between the rays, in consequence of the smallness of the radial paxillæ. The number of adambulacral spines is usually two but sometimes three.

HYMENASTER QUADRISPINOSUS Fisher.

Pl. 108, fig. 2; pl. 110, figs. 1–3; pl. 117, fig. 2.

Hymenaster quadrispinosus Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 315; Ann. and Mag. Nat. Hist., ser. 8, vol. 5, Feb., 1910, p. 170.

Diagnosis.—Adambulacral spines four or five; aperture papilla broad, sometimes with a sacculus at tip; paxillar spines three or four (rarely five), the paxillæ being arranged in nine rows along ray and forming specialized areas; lateral web when not contracted extending nearly to tip of ray, with transverse parallel linear spiracular areas; spiracula variable with age, very numerous, small, not in definite areas but everywhere among the spine tips; paxilla crowns of adjacent rows alternating.

Description.—The specimens exhibit extreme contractility of the interbrachial web and variability of contour and proportions. In most of the specimens this muscular interbrachial membrane is quite contracted, the paxillar crowns extending to edge of body, which has a very stellate form. In two specimens, however, the membrane is not contracted and exhibits transverse parallel lines of spiracula as described by Sladen in *H. nobilis*, and the form is more pentagonal with the paxillar areas sharply differentiated. The largest specimen has the rays too much recurved to measure. A slightly smaller one with contracted interbrachial webs has $R=51$ mm., $r=27$ mm., $R=1.88\ r$; a specimen with partly expanded web measures, $R=42$ mm., $r=29$ mm., $R=1.48\ r$.

Supradorsal membrane thin but tough, of a satiny luster, containing very numerous but inconspicuous crisscrossing muscle fibers (visible only in the larger Alaskan examples). Paxillar area comprising whole dorsal surface, except a free lateral muscular web which is usually so contracted as to be very inconspicuous.

Paxillæ with usually four spines (sometimes three, rarely five), which push up the membrane (no central spine), the individual paxillæ being easily distinguishable and arranged in nine rows along each ray, the paxillæ of adjacent rows alternating in a regular manner. Spiracula varying greatly in number according to age. In the immature type from off San Diego they are not numerous and are very inconspicuous, but in the adult Alaskan examples they are very numerous though small. In the smallest of these examples (R = 10 mm.) spiracula are very much fewer than in the largest. (See paragraph on young, below.) The spiracula when fully developed are exceedingly numerous all over the supradorsal membrane both between the paxillar crests and amid the spines, from the tops of which they tend to arrange themselves in radiating lines. They are thus not in definite areas, except on the interbrachial web, where the spiracula form parallel linear areas extending outward from the paxillar region. These lines occur from the interbrachial angle (the longest line being fourth or fifth from angle) nearly to tip of ray. As this fringing membrane is usually contracted these areas are then invisible and were entirely overlooked in the type where they can not be seen. The spiracula are not present between the spines of a paxilla crest in all the Alaskan specimens, being absent in those from station 2859. Oscular orifice large; valves triangular with a truncate summit, however; spinelets about eleven to sixteen to each valve, the seven or eight central ones subequal, the laterals graduated; membrane of valves rather thick; on base of each valve at either side a well-defined triangular spiracular area about one-third the height of the longer spines, containing many spiracula; in the membrane between adjacent valves numerous spiracula, which extend nearly to the distal edge of the valves; supradorsal membrane slightly raised along interradial lines in examples with reflexed rays.

Adambulacral spinelets flattened, tapering, sharp, in an oblique transverse, slightly curved comb of four or five, the outermost longest and most adorally placed, the rest graduated in length toward the inner, which is one-third to two-thirds smaller. Just external to the outermost and in line with the series is the broadly ovate, round-tipped aperture papilla, fitting tightly over the corresponding segmental aperture like a valve, the base of this papilla abruptly narrowed for articulation to the plate; the first papilla much larger than the rest and lying in the actinolateral membrane. In Bering Sea specimens the tip of some of the papillæ, especially proximally, is prolonged in a narrow membraneous sacculus or flap one-third to one and one-half the length of papilla. The outermost spine of the comb also has a fleshy tip of variable length. These sacculi are not present in the type, but that is a young specimen and the sacculi are very deciduous. Moreover, the Alaskan examples are not constant in this character as pointed out under "*Young*," on page 382.

The combined mouth plates are higher and narrower than in typical species of this genus. The medium suture is on the summit of a central eminence or keel of the combined plates, which slope off steeply on either side to the margin next to furrow. The actinostomial margin is slightly curved and slopes downward from the median suture and forms a rounded angle at the mouth of furrow. At this point is the greatest width of the combined plates. On this sloping free margin of each plate are four or five slender, tapering, pointed, marginal spines, the inner much the thickest and longest (about equaling interradial diameter of plate), and a short distance back of this is a similar slender subequal suboral spine. The inner marginal and suboral may have a sacculus; these are well developed in the largest Alaskan example, which also has them on the aperture papillæ and adambulacral spinelets.

Actinolateral membrane thin, the spines showing through, over thirty in mature specimens, the seventh to eleventh the largest.

Color in alcohol rose pink; in life a deeper rose, madder, or scarlet.

Anatomical notes.—Nidamental cavity spacious. Pedicels of paxillæ slender, shorter than spines, about as 1.75:3 along midradial region, and as 3:5.5 on lateralmost row; base of paxillæ with four long slender processes, imbricating with similar processes of four other paxillæ in such a way that very regular rhombic meshes are formed, except between the two lateral (=marginal) rows of paxillæ (which do not alternate as do the abactinal, but stand one above the other). Counting directly across ray from one superomarginal to another there are three rhombic meshes, or two complete ones and two halves; likewise omitting the two nonalternating rows of paxillæ of either side, there are five longitudinal rows of true abactinal paxillæ. Papulæ large, with many small divisions at the summit; there is one to each paxilla except the primary radial, and none occur within the circle formed of the primary radial (or ocular) paxillæ. The periproct membrane contains several rows of thin, spaced, roundish plates, which consist of a single layer of characteristic calcareous mesh. No calcareous deposits are discoverable in the abactinal integument (other than the paxillæ) and none occur in the supradorsal membrane. (Type, and specimen from station 3603 examined.)

Anal aperture a narrow slit; intestinal cœcum small, little more than a dilation of the intestine. Gonad (female) interradial; interradial septa with thin plates. Ampullæ large, proximally single, but farther along the ray with two parts (though essentially only two-lobed sacs). Tube feet in two rows, with a small sucking disk, except near end of ray where the feet have an attenuate pointed tip. First ambulacral ossicle enlarged and with the lateral wings of the large odontophore forming a strong mouth frame; several large muscles to the stomach are inserted on it.

Young.—The type is an immature specimen. The cruciform abactinal plates overlap slightly by the lobes, which are not fully developed.

A series of nine specimens from station 2859 are graduated in size from R=10 mm. to R=42 mm. and exhibit well the changes which take place from the young to the mature form. It is this instructive series which has led me to place the San Diego and Alaskan specimens in the same species, although adults of the latter appear at first sight to be considerably different in the possession of many more spiracula, as well as lappets or sacculi to the segmental papillæ. A specimen with R=15 mm. has the characteristic nine rows of alternating paxillæ (each with four spinelets) along the ray. The spiracula are much fewer than in the adult, are scattered between the paxillar crowns, and are apparently a trifle more numerous than in the type (although on account of the whiteness of the membrane it is difficult to see them in the latter). Adambulacral spines four, the aperture papilla as in the adult, but without any sacculus at the tip. The marginal mouth spines are variable, ranging from three to five in number and differing also somewhat in relative position. The innermost is abruptly larger and usually somewhat spaced from the laterals. It appears to be a suboral moved to a marginal position. The longest adambulacral spinelet sometimes has a short sacculus. The smallest specimens are essentially like the above except that it is increasingly difficult to make out spiracula.

This series of young indicates that the number of adambulacral spines, number of paxillar spines, number of rows of paxillæ along ray, and number of mouth spines do not differ to any important extent with age, but that the spiracula increase greatly with age, and integumentary appendages of spines also appear in older specimens, when the young do not possess them. The interbrachial webs increase with age and probably the special spiracular areas do not appear till the animal is nearly adult.

Type.—Cat. No. 22344, U.S.N.M.

Type-locality.—*Albatross* station 4387, off San Diego, California, (longitude of Point Conception), 1,059 fathoms, green mud; one specimen.

Distribution.—Bering Sea to San Diego, California, and probably south to the vicinity of Panama, 1,059 to 1,771 fathoms, mud and ooze.

Specimens examined.—Fifteen; besides the type, nine from station 2859, off Prince of Wales Island, Alaska, 1,569 fathoms, gray ooze; five from station 3603, Bering Sea, between the Pribilof Islands and Unimak Island (Aleutians), 1,771 fathoms, blue ooze.

Remarks.—There is a possibility that the Alaskan specimens may constitute a separate race. The lack of fully grown examples from the type-locality leaves the question open. However, the only difference is the greater number of spiracula in the Bering Sea examples. This character, as the specimens prove, varies greatly with age, and immature Alaskan examples are not essentially different from the type.

The foregoing description is an attempt to describe the species rather than a single specimen. The description of the immature type was given when the species was named, but this is incomplete for the species, and has accordingly been emended.

The very considerable number (four or five) of adambulacral spinelets separates this species from most others of the genus, placing it in section D of Sladen's Synopsis (1889, p. 494). It differs from *H. coccinatus* in the form of the adambulacral comb (compare figure with *Challenger* Asteroidea, pl. 91, fig. 12), lack of distinct muscular reticulations in supradorsal membrane, in having many more spiracula (as many as in *H. porosissimus*), in having a less widely expanded pair of mouth plates (and different armature), and in having an interbrachial and lateral muscular web. The abactinal muscular reticulations of *coccinatus* are very conspicuous, although the type is probably young. *H. quadrispinosus* differs from *H. præcoquis* [a] in having fewer paxillar spinelets, a paxillar area well differentiated from a lateral web, more numerous spiracula, and large and differently formed aperture papillæ. The aperture papillæ of *præcoquis* are very like those of

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[a] See Sladen *Challenger* Asteroidea, 1889, p. 524, pl. 90, figs. 5, 6; pl. 91, figs. 13–15.

Pteraster, being free on one margin only. The mouth plates are also different. Both species are from the Southern Ocean, west of the Crozet Islands, 1,375 fathoms.

In this section of *Hymenaster* must be ranged *H. platyacanthus* Ludwig and *H. purpureus* Ludwig from the Panama-Galapagos region. Without a direct comparison of specimens it is not possible to determine the validity of these forms, as no specific characters are figured. *H. platyacanthus* differs apparently in having a thin and tender supradorsal membrane, seven instead of nine rows of alternating paxillæ, deposits in the abactinal integument at base of papulæ, and in having the papulæ in the middle instead of in the corner of the meshes (some of the lateral papulæ are in the middle of the mesh in *quadrispinosus*). The deposits may be present only in old specimens, and I am not sure that the position of the papulæ may not vary. *H. purpureus* differs from *platyacanthus* according to Ludwig (1905, p. 196) in having a dark color, and a membraneous lappet or sacculus at the tip of the aperture papillæ. These differences are very trifling, as color is in starfishes an almost useless character, and the sacculus varies with age in *quadrispinosus*. *H. purpureus* is, perhaps, the same species as *H. quadrispinosus*, but I hesitate to place it in synonymy without specimens or figures for comparison.

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EXPLANATION OF PLATES.

Plate 1. *Eremicaster tenebrarius*

Fig. 1. Type; side view, showing cribriform organs
2. Californian specimen with small disk.
3. Alaskan specimen with few superomarginal spines.
4. Specimen with recurved rays; California.

Plate 2.

Fig. 1. *Eremicaster pacificus;* abactinal view.
2. Same; actinal view.
3. Same; ambulacral furrow, enlarged.
4. *Eremicaster tenebrarius;* abactinal surface of disk enlarged; Californian specimen.

Plate 3. *Ctenodiscus crispatus.*

Fig. 1. Specimen from Alaska, station 4223.
2. Specimen from the Sea of Japan.
3. Narrow-rayed variety, Alaska, station 4235.
4. Specimen from south coast of Hokushu, Japan, station 5039, 326 to 269 fathoms.

Plate 4. *Ctenodiscus crispatus.*

Fig. 1. Actinal view, Alaskan specimen.
2. Four-rayed specimen.
3. Actinal interradial area of dried specimen, enlarged.
4. Paxillæ, enlarged, deep-sea variety, Bering Sea, station 3307, 1,033 fathoms.
5. Specimen from station 4223^2.
6. Specimen from Sea of Japan, station 4818.

Plate 5. *Astropecten armatus.*

Fig. 1. Specimen from San Diego, California.
2. Same; specimen with smaller disk and fewer superomarginal spines (Beacon 3 Shoal

Plate 6.

Fig. 1. *Astropecten californicus;* typical; abactinal surface.
2. Same; actinal surface.
3. *Astropecten ornatissimus;* actinal surface
4. Same; abactinal surface.

Plate 7

Fig. 1. *Astropecten californicus;* paxillæ and superomarginal plates of ray, enlarged
2. *Astropecten ornatissimus;* paxillæ of disk and basal portion of ray, enlarged
3. *Astropecten armatus;* inferomarginal and adambulacral armature, base of ray
4. *Leptychaster anomalus;* abactinal paxillæ and superomarginal plates, enlarged
5. *Psilaster pectinatus;* side view of ray, enlarged, to show flattened infero- and superomarginal spines; specimen from Bering Sea, station 3601
6. *Astropecten armatus;* abactinal paxillæ, enlarged, to show coalescent granules from specimen shown in plate 5, fig. 1.
7. *Psilaster pectinatus;* type; side view of ray, enlarged, compare with fig. 5

Plate 8

Fig. 1. *Leptychaster arcticus;* abactinal surface, enlarged
2. *Leptychaster pacificus;* abactinal surface, enlarged; station 4194

Plate 9.

Fig. 1. *Leptychaster anomalus;* typical.
2. *Leptychaster pacificus;* actinal surface, enlarged; station 4194.
3. *Leptychaster propinquus;* type.
4. *Leptychaster arcticus;* actinal surface enlarged, from off Hokushu, Japan, station 5047.

Plate 10. *Psilaster pectinatus.*

Fig. 1. Abactinal surface of type.
2. Portion of same, enlarged, ray; superomarginal plates on right.
3. Actinal surface, enlarged.

Plate 11. *Dipsacaster eximius.*

Fig. 1. Abactinal surface, typical specimen.
2. Margin and adjacent abactinal paxillæ, enlarged; the upper end of inferomarginal plates on left.

Plate 12.

Fig. 1. *Dipsacaster borealis;* type.
2. Same; marginal plates and paxillæ, enlarged.
3. *Dipsacaster lætmophilus;* marginal plates and paxillæ, enlarged.

Plate 13.

Fig. 1. *Dipsacaster borealis;* actinal surface.
2. *Dipsacaster eximius;* actinal surface.

Plate 14.

Fig. 1. *Dipsacaster eximius;* portion of actinal surface, enlarged; adambulacral plates on right, inferomarginals on left.
2. *Dipsacaster borealis;* same.

Plate 15. *Dipsacaster lætmophilus.*

Fig. 1. Abactinal surface of type.
2. Actinal surface of type.

Plate 16.

Fig. 1. *Dipsacaster anoplus;* type, abactinal surface.
2. Same; actinal surface, enlarged.
3. *Dipsacaster eximius;* young, much enlarged.

Plate 17.

Fig. 1. *Dytaster gilberti;* type.
2. Same; two superomarginals, enlarged.
3. Same; abactinal paxillæ, enlarged.
4. *Thrissacanthias penicillatus;* young specimen, enlarged.

Plate 18. *Thrissacanthias penicillatus.*

Fig. 1. Abactinal view of type.
2. Portion of actinal surface, enlarged, type.
3. Inferomarginal spines, ray.
4. Actinal surface of small specimen.
5. Paxillæ of type, enlarged.

Plate 19. *Luidia foliolata.*

Fig. 1. Abactinal view of Californian specimen, considerably less than natural size.
2. Actinal surface of one ray.
3. Example from Queen Charlotte Sound, station 4203.

PLATE 20.

Fig. 1. *Luidia asthenosoma;* type.
2. *Luidia ludwigi;* type.
3. Same; upper end of inferomarginal plate, superomarginal and abactinal paxillae, enlarged.

PLATE 21.

Fig. 1. *Luidia asthenosoma;* actinal surface of type, enlarged.
2. *Luidia ludwigi;* same.
3. *Luidia foliolata;* side view of ray of Californian specimen, enlarged.
4. Same; similar view of specimen from station 4203 for comparison; outer inferomarginal spines are shown.
5. Same; portion of actinal surface of ray, enlarged; Californian example.

PLATE 22.

Fig. 1. *Benthopecten mutabilis;* type.
2. *Benthopecten acanthonotus;* type, abactinal view.
3. Same; specimen with large disk.
4. *Benthopecten claviger;* type.

PLATE 23.

Fig. 1. *Benthopecten acanthonotus;* abactinal surface of type, enlarged.
2. Same; specimen from station 2919; abactinal surface enlarged.
3. *Benthopecten mutabilis;* actinal surface enlarged, type.
4. *Nearchaster pedicellaris;* portion of abactinal surface of type, much enlarged.

PLATE 24.

Fig. 1. *Nearchaster aciculosus;* cotype.
2. *Nearchaster variabilis;* type; see also plate 119, fig. 1.
3. *Myonotus intermedius;* type.

PLATE 25.

Fig. 1. *Nearchaster pedicellaris;* type.
2. *Luidiaster dawsoni;* Note: the abactinal primary spinules have been rubbed off the distal part of ray; see plate 120.

PLATE 26.

Fig. 1. *Nearchaster aciculosus;* abactinal surface, enlarged.
2. Same, actinal surface, enlarged.
3. *Nearchaster aciculosus*, upper figure; *Luidiaster dawsoni*, lower figure, for comparison.

PLATE 27.

Fig. 1. *Myonotus intermedius;* type; actinal surface.
2. *Luidiaster dawsoni*, for comparison; station 3320.
3. *Nearchaster pedicellaris;* actinal surface.
4. *Nearchaster variabilis;* same.

PLATE 28.

Fig. 1. *Pectinaster agassizi evoplus;* type.
2. Same; actinal surface.
3. *Benthopecten acanthonotus*, young.

PLATE 29. *Odontaster crassus.*

Fig. 1. Abactinal surface of type.
2. Actinal surface.
3. Portion of actinal surface, enlarged, to show teeth and adambulacral armature.
4. Portion of abactinal surface, enlarged, the odd interradial superomarginal shown above and a primary basal plate below.

PLATE 30. *Gephyreaster swifti.*

Fig. 1. Abactinal view of largest specimen.
2. Actinal surface of type.
3. Abactinal paxillæ, enlarged.
4. Actinal surface of ray, enlarged, showing adambulacral, actinal intermediate, and marginal plates.

PLATE 31.

Fig. 1. *Pseudarchaster parelii;* specimen from station 3225.
2. Same; superomarginal plates and paxillæ, enlarged.
3. *Pseudarchaster parelii alascensis;* typical specimen.
4. Same; abactinal paxillæ, enlarged.
5. Same; superomarginal plates and adjacent paxillæ, enlarged.

PLATE 32. *Pseudarchaster pusillus.*

Fig. 1. Type; abactinal surface.
2. Variety with shorter rays.
3. Variety with large paxillæ.
4. Type; actinal surface, enlarged.

PLATE 33.

Fig. 1. *Pseudarchaster pusillus;* abactinal surface of type, enlarged.
2. Same; abactinal surface of specimen with large paxillæ, enlarged.
3. *Pseudarchaster parelii;* typical, actinal surface, enlarged.
4. *Pseudarchaster parelii alascensis;* actinal surface, enlarged.

PLATE 34. *Pseudarchaster dissonus.*

Fig. 1. Type; abactinal surface.
2. Type; portion of abactinal surface, base of ray, enlarged.
3. Portion of actinal surface of ray, enlarged, the adambulacral plates shown in lower right corner, the inferomarginals in upper left.

PLATE 35. *Mediaster æqualis.*

Fig. 1. Abactinal surface, specimen from station 4281.
2. Portion of abactinal surface enlarged; Alaskan specimen.
3. Actinal surface enlarged; Alaskan specimen.

PLATE 36. *Mediaster tenellus.*

Fig. 1. Type; abactinal surface, slightly enlarged.
2. Same; portion of actinal surface, enlarged.

PLATE 37.

Fig. 1. *Ceramaster japonicus;* large specimen from station 3331; specimen B referred to in text.
2. Same; specimen A from station 3330.
3. Same; portion of actinal surface for comparison with that of *C. patagonicus* below (fig. 4).
4. *Ceramaster patagonicus;* portion of actinal surface for comparison with *C. japonicus.*

PLATE 38.

Fig. 1. *Ceramaster patagonicus;* vicinity of Naha Bay, Behm Canal, Alaska, station 4228,.
2. Same; specimen from Bering Sea, for comparison.
3. *Ceramaster clarki;* type.
4. Same; portion of actinal surface, enlarged.

Plate 39. *Ceramaster leptoceramus.*

Fig. 1. Type; abactinal surface.
2. Portion of abactinal surface enlarged, showing adradial secondary plates, smaller than the primary plates. The same are shown in fig. 1
3. Actinal surface.

Plate 40.

Fig. 1. *Ceramaster arcticus;* large specimen from "Unalaska and Unga, Alaska," W. H. Dall, and a small one, for comparison, from Round Island, Coal Harbor, Shumagin Islands. Note the difference in superomarginal armature.
2. Same; actinal and abactinal surface, enlarged, of two specimens from Shumagin Islands.
3. *Pseudarchaster parelii alascensis;* very young specimen, much enlarged.

Plate 41. *Cladaster validus.*

Fig. 1. Type; abactinal surface, enlarged.
2. Same; actinal surface, enlarged.

Plate 42. *Hippasteria spinosa.*

Fig. 1. Abactinal view of a typical specimen.
2. Portion of abactinal surface of a dried specimen, much enlarged.
3. Portion of actinal surface of the same specimen, enlarged

Plate 43.

Fig. 1. *Hippasteria spinosa;* abactinal surface of a specimen from southern California, station 3661.
2. *Hippasteria spinosa kurilensis;* type, from Simushir, Kuril Island, station 4801. See also plate 121, fig. 1.

Plate 44. *Hippasteria heathi.*

Fig. 1. Abactinal surface of type, enlarged.
2. Portion of actinal surface, enlarged.

Plate 45. *Hippasteria californica.*

Fig. 1. Type; abactinal surface.
2. Portion of abactinal surface of dried specimen, enlarged.
3. Marginal plates, enlarged, the actinal surface uppermost, viewed from side.
4. Actinal surface of a ray, enlarged.

Plate 46. *Hippasteria leiopelta.*

Fig. 1. Actinal view of type, enlarged.
2. Madreporic body, enlarged.
3. Abactinal view of type.
4. Portion of abactinal surface, much enlarged.

Plate 47. *Cryptopeltaster lepidonotus.*

Fig. 1. Type; abactinal surface.
2. Same; actinal surface.

Plate 48. *Linckia columbiae*

Fig. 1. Three stages of a ray developing a new disk. In the ray above the buds of the new rays are just beginning to show; in the middle figure they are well started; the lower figure is a "comet" form.
2. Specimen from side to show the marginal plates.
3. Actinal surface.
4. Abactinal surface.
5. Abactinal surface of portion of ray, enlarged, to show relative size of plates and papular areas
6. Actinal surface, enlarged.
7. Marginal plates, denuded; also actinal intermediate plates to left, and abactinal on right.

PLATE 49. *Dermasterias imbricata.*

Fig. 1. Specimen from Barclay Sound, British Columbia.

2. Left figure: portion of arm of specimen from Puget Sound; the integument has been stripped from right half, showing plates; on left half, numerous pedicellariæ, in the abactinal integument.

Right figure: portion of abactinal wall of ray, dried and viewed from cœlomic side showing plates.

PLATE 50.

Fig. 1. *Leptychaster pacificus;* two adambulacral plates, proximal third of ray, × 10. 1*a*. Same; abactinal plates, papular area, at base of ray, from inside, × 20.

2. *Leptychaster anomalus;* two adambulacral plates from about middle of ray, × 10. 2*a*. Same; abactinal plates at base of ray from inside, × 20; from station 3263.

3. *Psilaster pectinatus;* fifth, sixth, and seventh adambulacral plates, medium-sized individual, station 3307; spines have been removed from middle plate, × 10. 3*a*. Same; admedian paxillæ, base of ray, × 10. 3*b* and 3*c*. Same; two views of odontophore, × 10.

4. *Astropecten armatus;* abactinal plates near base of ray, from inside, × 10. The large plates to left (*r*) constitute the carinal or radial series of ray.

5. *Astropecten californicus;* abactinal plates, from inside, × 10; *r*, radial series.

PLATE 51.

Fig. 1. *Astropecten ornatissimus;* sixth, seventh, and eighth adambulacral plates, type, × 12. 1*a*. Same; abactinal plates near base of ray from within, × 20; *r*, radial series; *ad*, adradial series; *p*, papula. 1*b*. Same; section of arm, × 6, showing the marginal, adambulacral (*ad*), superambulacral (*sa*), and ambulacral (*amb*) plates with their dorsal serrate edges. 1*c*. Same; a large paxilla from base of ray of type, enlarged.

2. *Astropecten californicus;* adambulacral plates, near base of ray, × 10; specimen from station 4559 having more pointed superadambulacral spines; *ab*, aboral enlarged subambulacral spine. 2*a*. Same; adambulacral plate from near base of ray, type, × 10.

3. *Astropecten armatus;* ninth and tenth adambulacral plates, × 10; specimen from Beacon 3 Shoal, San Diego, California.

PLATE 52.

Fig. 1. *Dipsacaster eximius;* ninth and tenth adambulacral plates, × 6; *ad*, adoral side of plate. 1*a*. Same; paxilla from radial area at base of ray, × 10. 1*b*. Same; larger paxilla from near center of disk, × 10. 1*c*. Same; abactinal plates from within, × 10; *r–r*, median radial series. Note the more numerous papulæ about the radial plates.

2. *Dipsacaster borealis;* eighth adambulacral plate, × 6. 2*a*. Same; one of the largest paxillæ (except those on madreporic plate) from base of ray, × 10. 2*b*. Same; abactinal plates, base of ray, × 10; *r–r*, median radial series, *x–x*, course of adradial muscle band.

3. *Dipsacaster lætmophilus;* ninth adambulacral plate, × 6. 3*a*. Same; one of the furrow spines, × 6. 3*b*. Same; paxilla from radial region, base of ray, × 10.

4. *Dipsacaster anoplus;* fifth and sixth adambulacral plates, × 10. 4*a*. Same; large paxilla from base of ray, × 10.

PLATE 53.

Fig. 1. *Thrissacanthias penicillatus;* abactinal paxillæ from near base of ray, type, × 10. 1*a*. Same; side view of a larger paxilla from disk, × 10. 1*b*. Same; eighth adambulacral plate, type; × 6; the adoral side of plate is on the right. 1*c*. Same; eighteenth plate from medium-sized specimen, × 6; *ad*, adoral side. 1*d*. Same; bifid marginal spines, type, × 6; superomarginal to left, inferomarginal ($_2$) to right. 1*e*. Same; abactinal plates at base of ray, × 5; *r–r*, radial series.

2. *Dipsacaster lætmophilus;* abactinal plates, base of ray, × 10; *r–r*, radial series.

Fig. 3. *Dytaster gilberti;* paxillæ from near base of ray, adjacent to marginal plates, showing pedicellariæ, × 20. 3*a* Same; fifth adambulacral plate and an isolated furrow spine from side to show bend; adoral side of plate to left, × 6.

4. *Eremicaster tenebrarius;* second to fourth adambulacral plates, × 10; specimen without superomarginal spines, from Southern Alaska, station 2859. 4*a*. Same; second to fourth adambulacral plates, type, × 10.

Plate 54.

Fig. 1. *Luidia asthenosoma;* tenth adambulacral plate, and marginal, × 10.

2. *Luidia ludwigi;* superomarginal paxillæ with pedicellariæ and upper end of inferomarginal plates showing pedicellariæ, from near base of ray of type, × 12. 2*a* Same; adambulacral, actinal intermediate plates (*int*) and portion of inferomarginal plate (*inf*) showing actinal pedicellariæ, × 10.

3. *Luidia foliolata;* adambulacral plate (seventeenth) and an actinal intermediate plate *int*; bottom of figure is adoral, × 5.

4. *Benthopecten claviger;* third adambulacral and first marginal plates, showing also four actinal intermediate plates; bottom of figure adoral.

5. *Benthopecten acanthonotus;* fourth adambulacral and second paired inferomarginal, × 8. *Int*, actinal intermediate plate, with spines forming part of pedicellaria; bottom of figure is adoral.

6. *Benthopecten mutabilis;* seventh adambulacral and fifth inferomarginal, × 8. 6*a*. Same; primary basal spine and neighboring abactinal plates, typical, × 6.

Plate 55.

Fig. 1. *Nearchaster aciculosus;* a primary plate on radial area of disk surrounded by smaller plates, type, × 10. 1*a*. Same; mouth plates, specimens from station 4402, × 5. 1*b*. Same, ninth and tenth adambulacral plates, adoral side to right, × 8.

2. *Nearchaster variabilis;* large specimen, station 3330; two primary plates from midradial region, base of ray; a smaller secondary plate and three papulæ, × 10. 2*a*. Same; tenth adambulacral plate, type, × 10; *ad*, adoral side of plate.

3. *Luidiaster dawsoni;* a primary and several secondary plates from near center of disk, × 10. 3*a*. Same; ninth adambulacral plate, specimen from station 4791, × 8, *ad*, adoral side of plate.

4. *Pectinaster agassizi evoplus;* abactinal plates from interradii between inner ends of two papularia showing pedicellariæ, enlarged. 4*a*. Same; adambulacral and inferomarginal plates showing pedicellariæ and spines, × 8; *a*, accessory marginal spinules; *int*, actinal intermediate plate.

Plate 56.

Fig. 1. *Benthopecten claviger;* abactinal spine from base of ray of type, × 6. 1*a*. Same; end of spine, enlarged. 1*b*. Same; abactinal plates at base of ray, × 8. *r–r*, radial line.

2. *Benthopecten acanthonotus;* abactinal plates from base of ray, × 8; *r–r*, radial line.

3. *Nearchaster aciculosus;* station 4353; abactinal plates showing the primary (*pr*) and secondary (*s*) and interspersed papular pores; *r–r*, radial line, × 8.

4. *Nearchaster variabilis;* station 3330; abactinal plates from radial region, base of ray, × 8.

5. *Luidiaster dawsoni;* abactinal plates, *r–r*, radial line, *pr*, primary radial plate, *p*, papulæ, × 8.

6. *Odontaster crassus;* tenth, eleventh, and twelfth adambulacral plates, × 10.

7. *Dermasterias imbricata;* four adambulacral plates cleared of tissue, seen from above, the spines bent backward; *a*, furrow spines; *b*, actinal spines, which are always immersed in tissue.

8. *Asterina miniata;* an actinal intermediate plate from near mouth plate showing serrate scar (dotted), × 6. 8*a*. Same; abactinal plates from inside, median radial row in middle (stippled), × 4.

Plate 57.

Fig. 1. *Pectinaster agassizi evoplus;* papularium drawn from inner side, showing disposition of plates; *r–r*, radial line; *p*, papulæ, × 8.

2. *Gephyreaster swifti;* specimen from station 4784, mouth plates, showing the inner angle or face toward actinostome, the peristomial membrane (*per*) below, the vertical suture between the plates (*s*), the median tooth (*d*), and the peculiar marginal series of spines which descend the sides of plate nearly to peristome; the spinelets nearest the actinostome are the lightest; the strictly marginal series of spinelets bordering furrow are marked *a*, × 6. 2*a*. Same; median tooth of type. 2*b*. Same; side view of abactinal plates from radial line near base of ray, type, × 10. 2*c*. Same; larger spines from inferomarginals, × 20.

3. *Mediaster tenellus;* fourth adambulacral plate, × 10. 3*a*. Side view of furrow spine. 3*b*. Pedicellaria on first adambulacral plate. 3*c*. Pedicellaria from an actinal intermediate plate just back of mouth plates, × 10. 3*d*. A large paxilla from proximal radial region of dorsal surface, × 10.

4. *Pseudarchaster pusillus;* seventh adambulacral plate of type, × 10. 4*a*. Same; adambulacral plates showing pectinate pedicellariæ.

5. *Pseudarchaster parelii;* specimen from station 3225, ninth adambulacral plate; specimen with very coarse spinelets, × 8.

6. *Pseudarchaster parelii alascensis;* twelfth adambulacral plate, type, × 9.

7. *Pseudarchaster dissonus;* third, fourth, and fifth adambulacral plates with adjacent pedicellariæ; *ad*, adoral side of plate; *x*, jaw of pedicellaria on adambulacral plate; *int*, intermediate plate, the three small spinelets being on the actinal intermediate plate and bordering the furrow, × 5. 7*a*. Same; second, third, and fourth adambulacral plates of specimen from station 3601, to show slightly different pedicellariæ; adoral side of plates to left, × 10.

Plate 58.

Fig. 1. *Ceramaster arcticus;* specimen from station 3212, two adambulacral, and two adjacent intermediate plates (*int*), small specimen, × 10.

2. *Ceramaster clarki;* eighth and ninth adambulacral plates, × 10. 2*a*. Same; actinal intermediate pedicellaria, near above plates, × 10. 2*b*. Same; crown of radial plate showing pedicellaria, × 10.

3. *Ceramaster leptoceramus;* adambulacral plate, × 10. 3*a*. Same; one of the radial plates with three secondary paxillæ from proximal radial region, × 15.

4. *Cryptopeltaster lepidonotus;* third and fourth adambulacral and an actinal intermediate plate; adoral side to the left, × 5. 4*a*. Same; two primary plates from abactinal surface, radial region, one with a tubercle, the other with characteristic bivalved pedicellaria; between the two are numerous secondary ossicles, × 8.

5. *Hippasteria heathi;* eleventh adambulacral and adjacent actinal intermediate plate, × 5. 5*a*. Same; abactinal plates, proximal radial region; specimen partly dry and papulæ shrunken, × 5.

6. *Hippasteria leiopelta;* two adambulacral and an actinal intermediate plate, partly dry, × 10.

7. *Poraniopsis inflata;* three adambulacral plates from near middle of *R*, the furrow spines above, and three views of actinal adambulacral spines, below; on the right the actinal spine is bent so as to be parallel with furrow spines, of which the upper or grooved side is shown; type, × 5. 7*a*. Same; from station 4362, similar view to above from a variety with slender adambulacral spines, × 5.

8. *Poraniopsis inflata flexilis;* type; three adambulacral spines; *f*, furrow and *a*, subambulacral spine, with flange of tissue; × 5.

Plate 59.

Fig. 1. *Mediaster æqualis;* abactinal plates from proximal radial region, showing internal connecting ossicles (dotted); *p*, papulæ; *r*, radial series, × 8. 1*a*. Same; bottom of a radial plate; 1*b*. Side view of same. 1*c*. Same; eighth to tenth ambulacral plates showing the small superambulacral ossicles dotted; *am*, ambulacrals; *ad*, adambulacrals; *int*, actinal intermediate plates; *sup*, superambulacrals, × 8.

Fig. 2. *Mediaster tenellus;* abactinal plates, proximal radial region, showing internal connecting ossicles, papulæ, lined; *r–r* radial series, × 10.

3. *Ceramaster japonicus;* abactinal plates from inside, proximal radial region, × 8.
4. *Pseudarchaster pusillus;* abactinal plates from inside, near base of ray; *r*, radial series, × 10.
5. *Gephyreaster swifti;* specimen from station 4784, abactinal plates from inside; *R*, primary radial plate; *r*, radial series, × 7. *5a* Same; abactinal plates of type from near base of ray; *r–r*, radial series, × 5.
6. *Ceramaster clarki;* abactinal plates from inside, showing the curious lobes, *ad*, adradial series, *r*, radial series, × 8. *6a*. Same; large adradial paxilla, showing the concavity at base (dotted) and the pit of pedicellarian muscles (*p*.)

PLATE 60.

All drawings are from the inner or cœlomic side.

Fig. 1. *Ceramaster arcticus;* abactinal plates from proximal radial region, showing radial series of plates (*r*) and the differently formed dorsolateral plates on either side. These have the lobes developed on the side toward radial line. Papulæ represented by small circles, × 8.

2. *Ceramaster leptoceramus;* abactinal plates from proximal radial region, showing the radial series (*r*) and on either side the small secondary plates, × 8.
3. *Ceramaster patagonicus;* abactinal plates; *pr*, primary radial, *r*, radial series.
4. *Hippasteria spinosa;* abactinal plates from proximal radial region, showing primary (*pr*) and secondary (*s*) plates and papulæ (*p*), × 5.
5. *Hippasteria californica;* abactinal plates; *r*, radial plates; small secondary intermediate plates surrounding them; *ad*, adradial plate; papulæ shown as small dark circles, × 5.
6. *Hippasteria heathi;* abactinal skeleton midradial region; the secondary plates are deeper than wide and form a fenestrated reticulum; papulæ cross-lined. × 5.
7. *Cryptopeltaster lepidonotus;* abactinal plates; the larger are the primary plates; papulæ, small dark circles, × 5.

PLATE 61. *Asterina miniata.*

Fig. 1. Six-rayed specimen from Monterey Bay, California.

2. Seven-rayed specimen, same locality.
3. Specimen from north of La Paz, Gulf of California, station 3001.
4. Specimen from Clayoquot Sound, British Columbia, dried without first being hardened.

PLATE 62. *Asterina miniata.*

Fig. 1. Apical region, denuded.

2. Actinal surface, specimen from Monterey Bay, California.

PLATE 63. *Poraniopsis inflata.*

Fig. 1. Type and two young; abactinal view.

2. Type; actinal view.

PLATE 64. *Poraniopsis inflata flexilis*, type, abactinal view.

PLATE 65. *Henricia sanguinolenta.*

Fig. 1. Actinal view of a specimen from station 4803, and abactinal, station 4281. These are as near typical as are any Alaskan specimens.

2. One ray of a giant specimen, variety C, from station 4778, and a specimen referable to the same variety from station 4784.

PLATE 66. *Henricia sanguinolenta*, varieties.

Fig. 1. Giant specimen, variety C, station 4784.

2. Small portion of ventro-lateral surface of typical *H. sanguinolenta* for comparison with fig 3.
3. Actinal surface of fig. 1, enlarged, showing marginal plates below; see also fig. 5.
4. Small portion of abactinal surface of fig. 5, enlarged (variety C.)
5. Actinal view of a ray from a giant specimen, variety C, from station 4778; abactinal surface shown in plate 65, fig. 2. These are believed to be hybrids.

PLATE 67. *Henricia sanguinolenta eschrichtii.*

Fig. 1. Specimen from Kadiak Island, enlarged.
2. Single ray, specimen from Kadiak Island.
3. Specimen from Bering Island.

PLATE 68.

Fig. 1. *Henricia sanguinolenta eschrichtii;* specimen showing young grouped around mouth, enlarged.
2. Same; a nearly pentagonal specimen from Attu Island.
3. *Henricia sanguinolenta*, variety E. Three specimens.

PLATE 69. *Henricia leviuscula.*

Fig. 1. Specimen from Puget Sound (variety A).
2. Three specimens of the small variety found at Monterey Bay, California, and other places, (variety F), enlarged.

PLATE 70.

Fig. 1. *Henricia leviuscula;* specimen from Puget Sound (variety A), enlarged.
2. Portions of rays, enlarged for comparison *a*, *Henricia leviuscula*, variety A. *b*, Same; variety B, slender-rayed specimen from station 4205. *c*, Same; variety B, Monterey Bay, California. *d*, *Henricia leviuscula annectens.*

PLATE 71.

Fig. 1. *Henricia leviuscula annectens*, for comparison with fig. 2.
2. *Henricia leviuscula*, variety A., Puget Sound.
3. *Henricia leviuscula annectens;* actinal view, for comparison with portion of ray of *H. leviuscula.*

PLATE 72. *Henricia leviuscula multispina.*

Fig. 1. Type; station 4779.
2. Variety from Kadiak Island.
3. Variety from station 4771.
4. Specimen from station 2842.

PLATE 73. *Henricia leviuscula multispina.*

Fig. 1. Type; portion of disk and ray enlarged to show paxillæ.
2. Type; portion of actinal surface enlarged.

PLATE 74. *Henricia leviuscula dyscrita.*

Fig. 1. Type; abactinal view.
2. Actinal surface of specimen from off Wilmington, California, 47 fathoms.
3. Aberrant variety from station 4420; abactinal view.
4. Same specimen; actinal surface.
5. Portion of abactinal surface of two rays, enlarged.

PLATE 75. *Henricia aspera.*

Fig. 1. Cotype; actinal surface.
2. Type; abactinal.
3. Variety from California (station 4551).
4. Cotype; portion of actinal surface, enlarged.
5. Type; abactinal surface, enlarged to show sunken papular areas and small spinelets.

PLATE 76. *Henricia longispina.*

Fig. 1. Type; abactinal surface, enlarged.
2. Same; actinal surface, enlarged.

PLATE 77.

Fig. 1. *Henricia asthenactis;* abactinal view of type, and actinal view of cotype
2. *Henricia longispina aleutica;* type.

PLATE 78.

Fig. 1. *Henricia polyacantha;* type.
2. *Henricia clarki;* type.
3. Same; type, actinal surface.
4. *Henricia polyacantha;* type, actinal surface.

PLATE 79. *Lophaster furcilliger.*

Fig. 1. Type; abactinal surface.
2. Type; actinal surface, enlarged

PLATE 80. *Lophaster furcilliger vexator.*

Fig. 1. Type; abactinal surface.
2. Type; actinal surface.

PLATE 81. *Solaster endeca*, from off the Shumagin Islands, station 2851, Alaska.

PLATE 82.

Fig. 1. *Solaster endeca;* station 2851; portion of actinal surface.
2. Same; station 4246 (*S. galaxides* Verrill); for comparison with fig. 1.
3. *Solaster stimpsoni;* station 4205.
4. *Solaster endeca;* station 4246 (*S. galaxides* Verrill).

PLATE 83. *Solaster stimpsoni.*

Fig. 1. Specimen from station 4205; actinal view.
2. Specimen from Vancouver Island (Port Renfrew).
3. Specimen from Kadiak Island, Alaska.
4. Portion of actinal surface, enlarged; Kadiak Island.
5. Paxillæ of disk, enlarged; specimen shown in fig. 3.

PLATE 84. *Solaster dawsoni.*

Fig. 1. Specimen from Monterey Bay, California.
2. Specimen from Cape Mendocino, California; paxillæ and portion of madreporic body.

PLATE 85. *Solaster dawsoni.*

Fig. 1. Specimen from Point Franklin, Alaska.
2. Specimen from Straits of Juan de Fuca (Port Renfrew, British Columbia).

PLATE 86. *Solaster dawsoni.*

Fig. 1. Actinal surface of specimen from Monterey Bay.
2. Abactinal surface of variety from station 3466.

PLATE 87. *Solaster paxillatus.*

Fig. 1. Large specimen from station 3331.
2. Paxillæ, enlarged.

PLATE 88. *Solaster paxillatus;* actinal surface of specimen shown in plate 87, fig. 1.

Plate 89. *Solaster paxillatus*, variety.

Fig. 1. Specimen from station 2853.
2. Similar specimen from station 4792, showing actinal surface. Compare with plate 88.

Plate 90. *Solaster exiguus.*

Fig. 1. Type; actinal surface.
2. Same; abactinal surface.

Plate 91. *Solaster borealis.*

Fig. 1. Type; abactinal surface.
2. Seven-rayed specimen from station 3607.
3. Abactinal paxillæ, enlarged.

Plate 92. *Solaster borealis.*

Fig. 1. Two specimens of the Californian variety; abactinal surface of specimen from station 4528; actinal surface of specimen from station 3343.
2. Portion of actinal surface of type, enlarged.

Plate 93. *Solaster hypothrissus.*

Fig. 1. Type; abactinal surface.
2. Same; portion of actinal surface, enlarged.

Plate 94. *Solaster papposus.*

Fig. 1. Typical specimen; station 2843.
2. Variety C from station 4788.
3. Variety C from off Oregon, station 3051.
4. Variety A from station 3518.
5. Variety A from station 4795.
6. Nearly typical specimen from station 2846.

Plate 95. *Solaster japonicus.*

Fig. 1. Type from station 4818.
2. Specimen from station 4859.

Plate 96. *Heterozonias alternatus.*

Fig. 1. Actinal surface of specimen from station 4400.
2. Abactinal surface; station 4400.
3. Abactinal paxillæ, dried; station 3343.

Plate 97. *Peribolaster biserialis.*

Fig. 1. Portion of actinal surface of type, and abactinal surface of specimen from station 3317.
2. Abactinal surface of type and portion of cotype, dried.

Plate 98. *Pteraster militaris.*

Fig. 1. Abactinal surface of specimen from station 2846.
2. Same specimen; actinal surface.

Plate 99. *Pteraster trigonodon.*

Fig. 1. Type; abactinal surface.
2. Same; actinal surface.

PLATE 100.

Fig. 1. *Pteraster marsippus;* abactinal surface.
2. *Pteraster jordani;* abactinal surface.

PLATE 101.

Fig. 1. *Pteraster jordani;* actinal surface.
2. *Pteraster marsippus;* actinal surface.

PLATE 102.

Fig. 1. *Pteraster coscinopeplus;* type; abactinal surface.
2. *Pteraster pulvillus;* abactinal surface.
3. *Pteraster coscinopeplus;* type; actinal surface.
4. *Pteraster pulvillus;* actinal surface.

PLATE 103.

Fig. 1. *Pteraster tesselatus arcuatus;* type.
2. *Pteraster temnochiton;* abactinal view of type.
3. Same; actinal surface.

PLATE 104. *Pteraster tesselatus.*

Fig. 1. Actinal surface of small dried specimen from station 4205.
2. Actinal surface of specimen from station 4222.
3. Abactinal surface of specimen from station 3461.
4. Abactinal surface of specimen from station 4235.
5. Actinal surface of specimen from station 3222.

PLATE 105. *Pteraster obscurus.*

Fig. 1. Large seven-rayed specimen, showing position of young escaping through supradorsal membrane in interradius. This opening was made with a knife, and the young one placed in same position as that referred to in text.
2. Small six-rayed example; actinal surface.
3 and 4. Abactinal surface of two six-rayed specimens.

PLATE 106. *Pteraster obscurus.*

Fig. 1. Small eight-rayed specimen, enlarged (=*Pt. octaster* Verrill).
2. Actinal surface of a six-rayed specimen, enlarged.

PLATE 107. *Diplopteraster multipes.*

Fig. 1. Large specimen from station 4784, abactinal view.
2. Actinal surface of small specimen from station 4235.

PLATE 108.

Fig. 1. *Hymenaster kœhleri;* type.
2. *Hymenaster quadrispinosus;* portion of supradorsal membrane, enlarged.

PLATE 109. *Hymenaster perissonotus*

Fig. 1. Abactinal surface of specimen from station 3307.
2. Actinal surface, specimen from station 3074.

PLATE 110. *Hymenaster quadrispinosus.*

Fig. 1. Specimen from station 2859.
2 and 3. Specimens from station 3603.

PLATE 111.

Fig. 1. *Dendrogaster arbusculus* (new species); natural size; in specimen of *Hippasteria californica.*

2. *Henricia polyacantha;* tenth adambulacral plate of cotype from furrow, showing six furrow spinelets; × 15. 2*a*. Same; seventh adambulacral plate of cotype, side view, × 15. 2*b*. Same; dorsal skeleton, inner side, the individual plates not shown; the regular transverse rows of papulæ to left; radial (*r*) series, dotted, × 6.

3. *Henricia longispina;* fourth adambulacral plate, from side, × 10. 3*a*. Same; inner view of abactinal and lateral plates showing papular areas; *sup*, superomarginal, × 6.

4. *Henricia asthenactis;* abactinal plates near base of ray to show papular areas and spinelets; *r*, radial series, × 10. 4*a*. Same; adambulacral plates near base of ray, the spines being turned adorad, showing the aboral side of each plate; *f*, furrow spinelet; *inf*, inferomarginal spinelets; *p*, papulæ, × 10.

5. *Henricia clarki;* ninth adambulacral plate, from side; three furrow spinelets, × 15.

6. *Henricia leviuscula;* midradial (ray) portion of abactinal skeleton from the outside, × 6.

PLATE 112.

Fig. 1. *Poraniopsis inflata;* abactinal skeleton from the inside of a specimen with unusually stout trabeculæ, showing two rows of papular areas between the midradial (*car*) and superomarginal (*sup*) series of plates; *ad*, adradial plates; *a*, papular area of specimen from station 4471, where the granules are fairly numerous; *b*, *c*, showing the condition in specimen from station 4362, where granules are less numerous, × 3.

2. *Poraniopsis inflata flexilis;* abactinal skeleton, from inside, showing the very large adradial papular areas; *ad*, adradial series; *car*, midradial or carinal series; *sup*, superomarginals. The primary plates are cross-lined. The dotted line shows the position of the adradial series of intermediate ossicles of *inflata*, × 3.

3. *Henricia clarki;* abactinal skeleton from within, radial region, base of ray. The individual plates of primary mesh are not shown, but the lower secondary plates are dotted; papulæ not shown, × 6.

4. *Solaster exiguus;* two adambulacral, and adjacent marginal plates of type; *inf*, inferomarginal; *sup*, superomarginal, × 15. 4*a*. Same; two inferomarginal spines, enlarged. 4*b*. Same; pseudopaxillæ from proximal radial region, much enlarged.

5. *Heterozonias alternatus;* cotype, from station 4400; adambulacral, actinal intermediate (*int*), two prominent (infero-) marginal (*inf*), two superomarginals (*sup*), and four abactinal plates (*ab*); *p*, papulæ, × 8. 5*a*. Same; adambulacral plate of type, × 8. 5*b*. Same; skeleton of dried specimen (station 4317), base of ray, showing the large papular areas and small spaced paxillæ; papulæ cross-lined, × 8.

PLATE 113.

Fig. 1. *Solaster dawsoni;* adambulacral, marginal and two dorsolateral paxillæ from specimen from Monterey Bay, × 8; *inf*, inferomarginal plate; *sup*, superomarginal plate, *pax*, paxilla; *p*, papula.

2. *Solaster borealis;* station 3071; abactinal paxillæ and papulæ, radial region, near base of ray, × 10. 2*a*. Same; adambulacral plate and adjacent marginal, type; *int*, intermediate spinelet, × 8.

3. *Solaster paxillatus;* station 3331; adambulacral, and marginal plates from basal third of ray, × 8; *inf*, inferomarginal and *sup*, superomarginal plates.

4. *Solaster japonicus;* station 4818; adambulacral plate, × 8.

5. *Solaster hypothrissus;* type; adambulacral and actinal intermediate (*int*) plate, × 8. 5*a*. Same; abactinal paxillæ, type, × 6.

PLATE 114.

Fig. 1. *Lophaster furcilliger*, radial paxilla, × 10. 1*a* to 1*e*. Spinelets from abactinal paxillæ. 1*f*. Same; superomarginal spine. 1*g*. Same; subambulacral spine, shallow-water variety, southern California, × 35.

Fig. 2. *Lophaster furcilliger vexator;* two paxillar spines, enlarged. 2*a*. Same; two subambulacral spines, type, × 20. 2*b*. Same; abactinal plates of ray, seen from inner side, the irregular plating of the radial region shown at *r*, × 5.

3. *Peribolaster biserialis,* cotype, dried; three adambulacral and adjacent inferomarginal plates, × 15. 3*a*. Same; adambulacral and inferomarginal spines of undried specimen, station 3317, × 8. 3*b*. Same; mouth plates, × 8. 3*c*. Same; two papulæ and fascicule of spinelets with enveloping tissue, station 3317, × 8.

Plate 115.

Fig. 1. *Hymenaster perissonotus;* station 3307; abactinal and marginal plates, to show the small size and arrangement of former. The plates have lobes a trifle heavier than in typical southern specimens, and in some specimens the plates are less joined along the radial region; *ad*, adradial series; *r*, radial series; *s*, superomarginals; *inf*, inferomarginals, × 5. 1*a*. Same; inferomarginal paxilla. 1*b*. Radial paxilla for comparison, taken on same transverse line and drawn to same scale, × 6. 1*c* to 1*e*. Same; superomarginal (*c*), adradial (*d*), and radial (*e*) plates of topotype to show the extremely slender lobes, × 6.

2. *Pteraster trigonodon;* spicules from supradorsal membrane, much enlarged

3. *Pteraster temnochiton;* spicules from supradorsal membrane, much enlarged.

4. *Pteraster marsippus;* spicules from supradorsal membrane, much enlarged.

5. *Peribolaster biserialis;* cotype; abactinal skeleton and fascicules of spinelets of dried specimen; papulæ shown in one mesh; *r*, primary radial plate, × 8.

Plate 116.

Fig. 1. *Pteraster marsippus;* eleventh and twelfth adambulacral combs, the eleventh bent back to show the small pocket external to aperture papilla; note the depressions in aboral surface of adambulacral web; dotted line parallel to actinolateral spine shows where adambulacral web joins membrane; depth of pouch shown by dotted line; *ac*, actinolateral spine; *ap*, aperture papilla; *p*, pouch, × 5.

2. *Pteraster trigonodon;* adambulacral armature, type; *ac*, actinolateral spine; *ap*, aperture; *p*, papilla, × 10. 2*a*. Same; mouth plates; complete armature of one plate only, × 6

3. *Pteraster temnochiton;* paxilla seen from side, showing also interior of nidamental cavity; *e*, embryo, actinal side up; *p*, papula, × 10. 3*a*. Same; adambulacral armature; lettering as in fig. 2. 3*b*. Same; suboral spine, × 10.

4. *Pteraster coscinopeplus;* mouth plates, × 6.

5. *Lophaster furcilliger;* fourth and fifth adambulacral, an intermediate (*int*), and second inferomarginal (*inf*) plates, × 10.

Plate 117.

Fig. 1. *Pteraster jordani;* adambulacral armature and part of adjacent actinolateral spine, × 5. 1*a*. Same; abactinal paxilla with papula; the longer spine *s* is broken, × 5 1*b*. Same; mouth plates, specimen from station 3346, × 5.

2. *Hymenaster quadrispinosus;* station 3603; adambulacral armature, large Alaskan specimen, × 6.

3. *Hymenaster perissonotus;* topotype; armature of third adambulacral plate; spines have been removed from second; × 6. 3*a*. Same; topotype; mouth plates, × 5.

4. *Hymenaster kœhleri;* mouth and adjacent adambulacral plates, × 3.

Plate 118.

Fig. 1. *Myonotus intermedius;* mouth plates, × 6; some of the suboral spines removed from left plate. 1*a*. Same; fifth and sixth adambulacral and third inferomarginal plates, × 6. 1*b*. Same; abactinal paxilla. 1*c*. Same; abactinal paxilla from side. 1*d*. Same; sixth superomarginal plate with spines, from side, × 6. 1*e* Thirty-fifth adambulacral plate with three furrow spinelets. 1*f*. Fourth adambulacral plate, one furrow spine, × 6.

2. *Nearchaster pedicellaris;* mouth plates of type, × 6; some of the suborals have been removed from left side.

3. *Nearchaster aciculosus;* sixth superomarginal and inferomarginal from side, showing the armature, × 6.

PLATE 119.

Fig. 1. *Nearchaster variabilis;* abactinal surface of a specimen having the maximum number of papulæ.
2. *Luidiaster dawsoni;* abactinal view of a young specimen, enlarged.

PLATE 120. *Luidiaster dawsoni.*

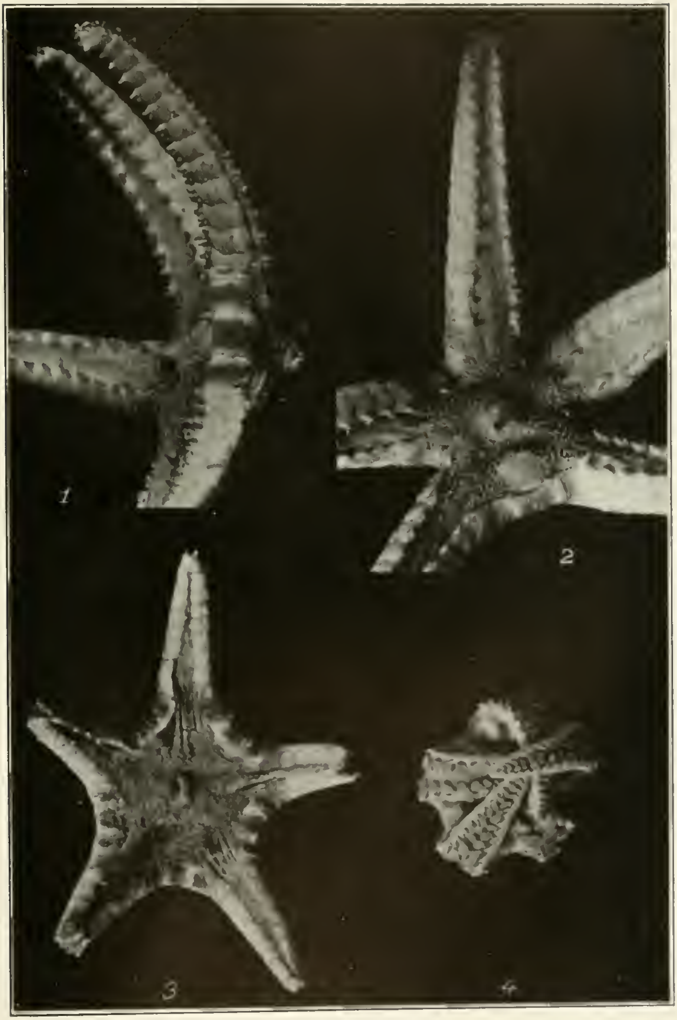
Fig. 1. An abactinal view of a medium-sized specimen, from station 4792, enlarged.
2. Actinal surface of same specimen, enlarged.

PLATE 121.

Fig. 1. *Hippasteria spinosa kurilensis;* type, actinal surface.
2. *Hippasteria leiopelta armata;* type, actinal surface.

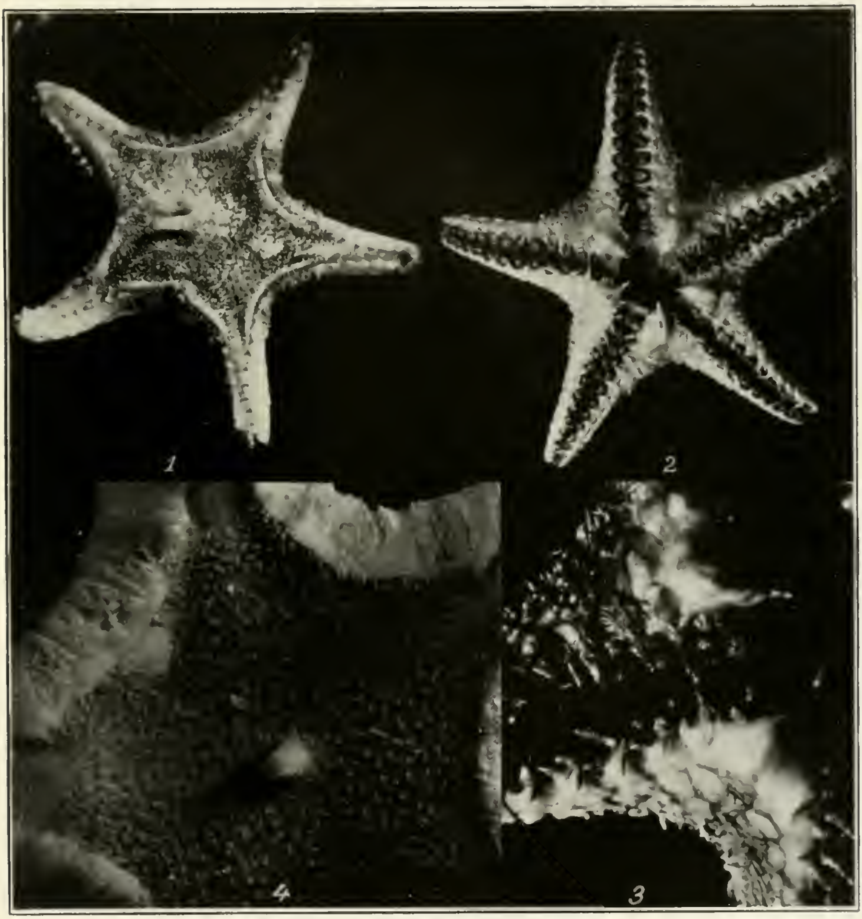
PLATE 122. *Hippasteria leiopelta armata.*

Fig. 1. Abactinal surface of small example.
2. Abactinal surface of type.



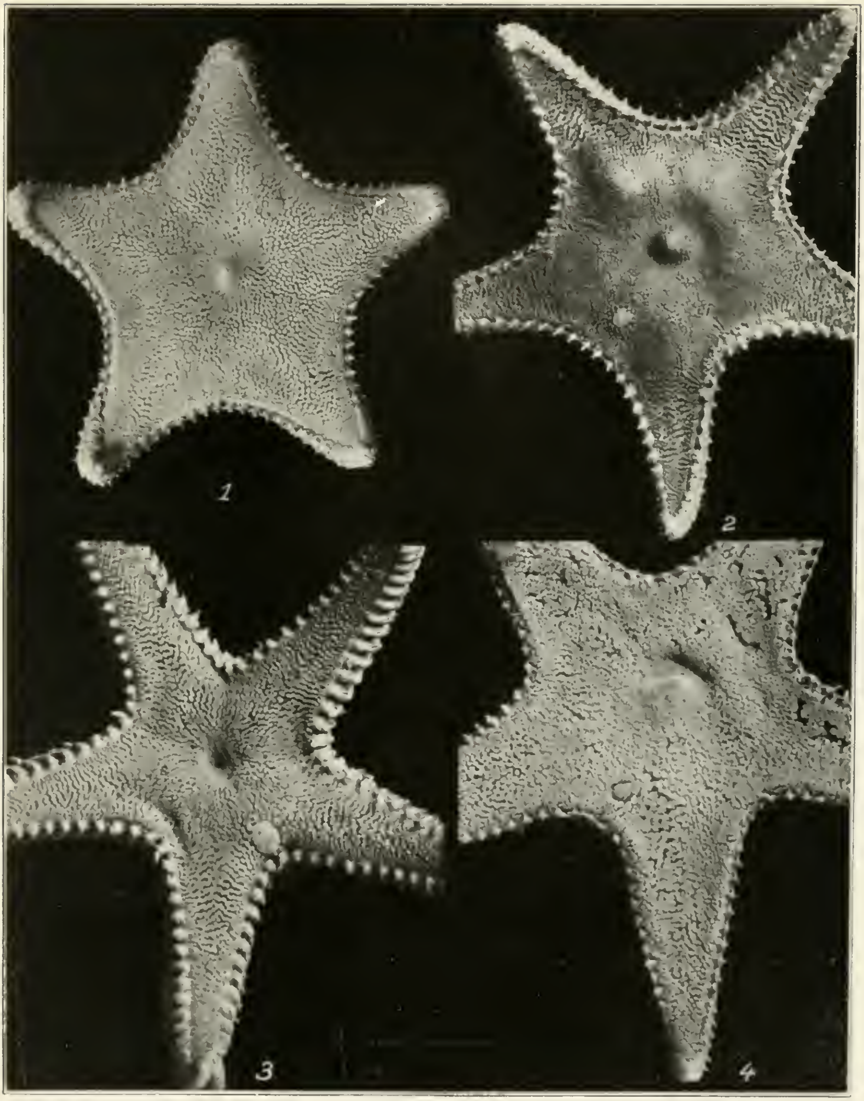
EREMICASTER TENEBRARIUS.

FOR EXPLANATION OF PLATE SEE PAGE 391



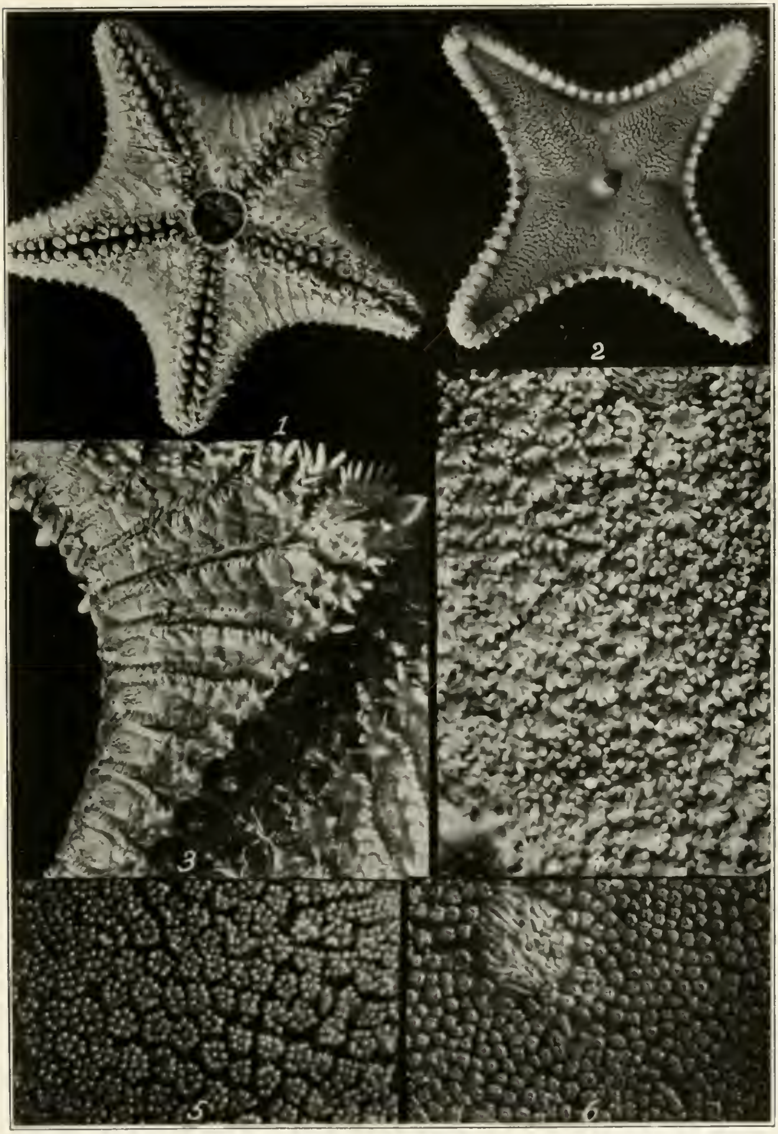
1-3. Eremicaster pacificus 4. E. tenebrarius.

For explanation of plate see page 391.



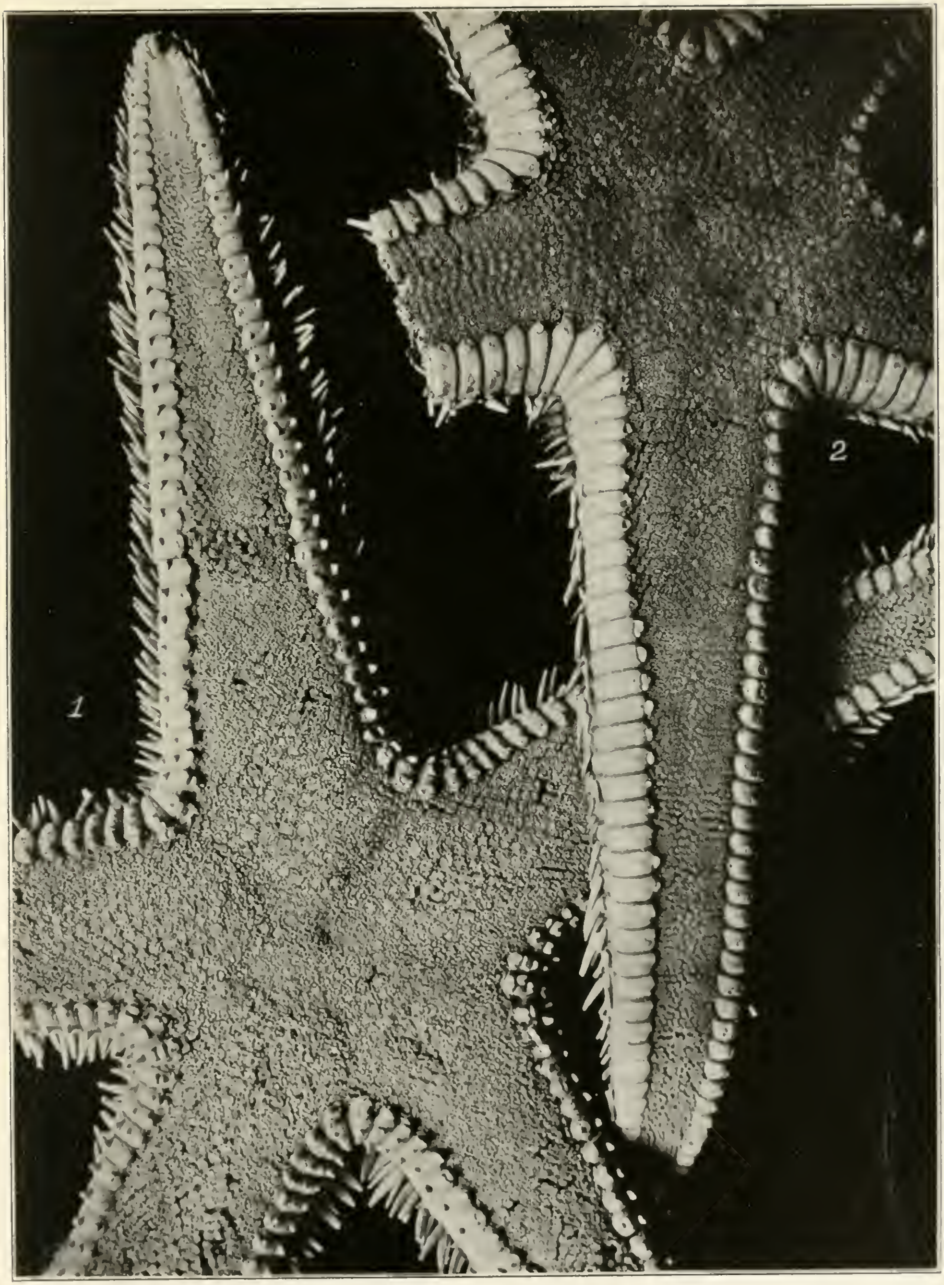
CTENODISCUS CRISPATUS.

FOR EXPLANATION OF PLATE SEE PAGE 391.



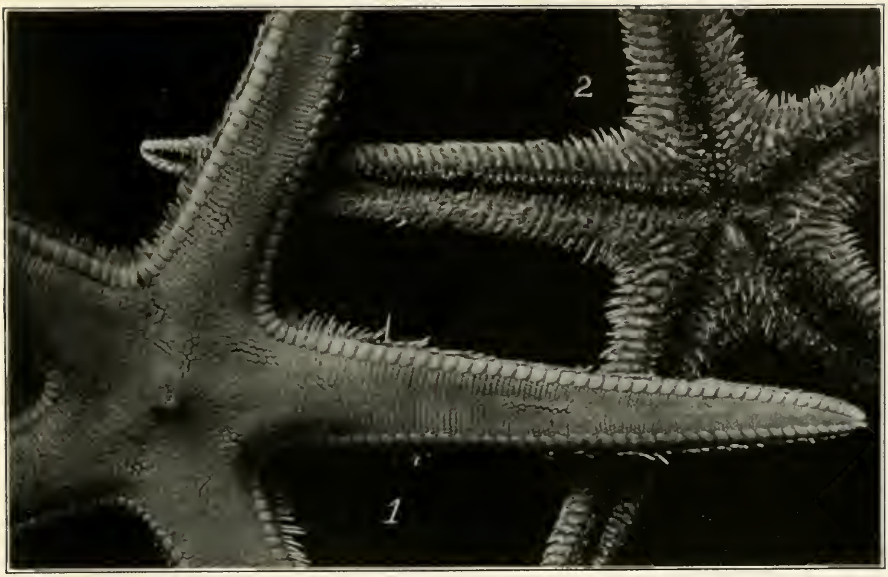
CTENODISCUS CRISPATUS.

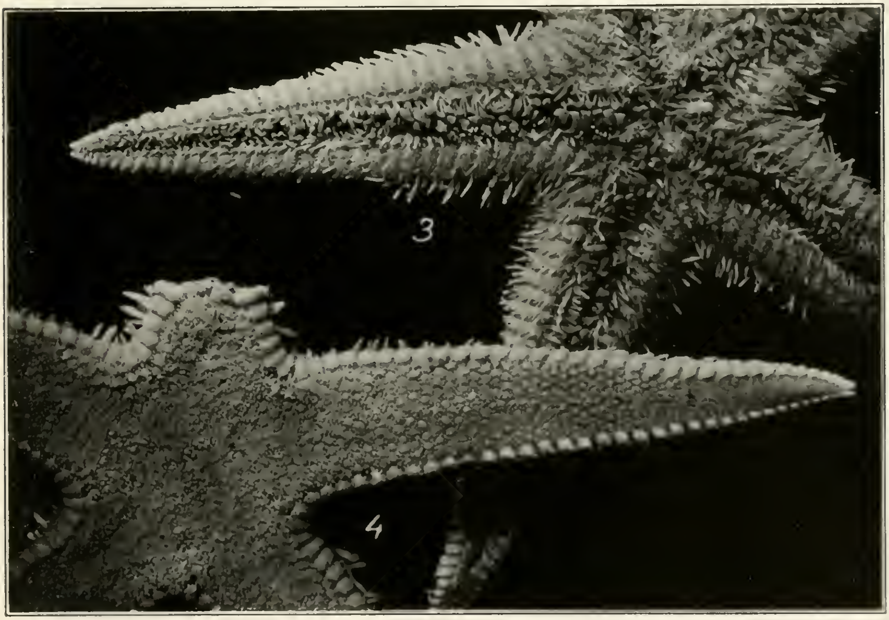
FOR EXPLANATION OF PLATE SEE PAGE 391.



ASTROPECTEN ARMATUS.

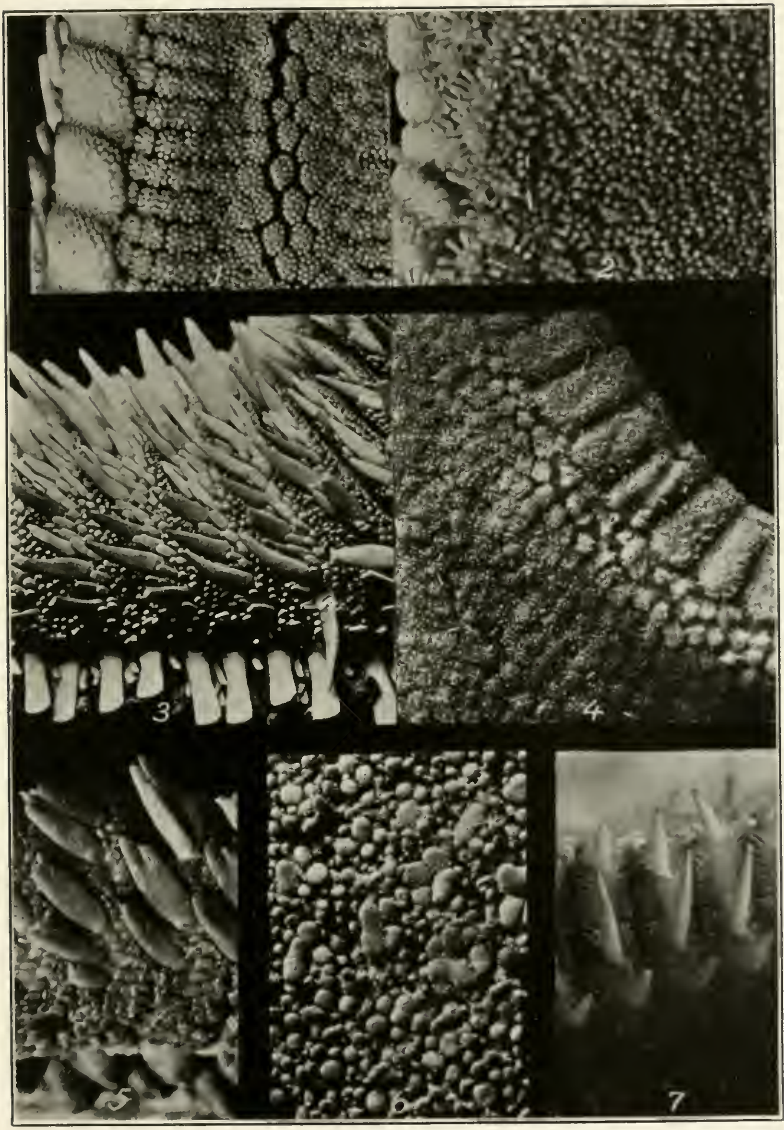
For explanation of plate see page 331





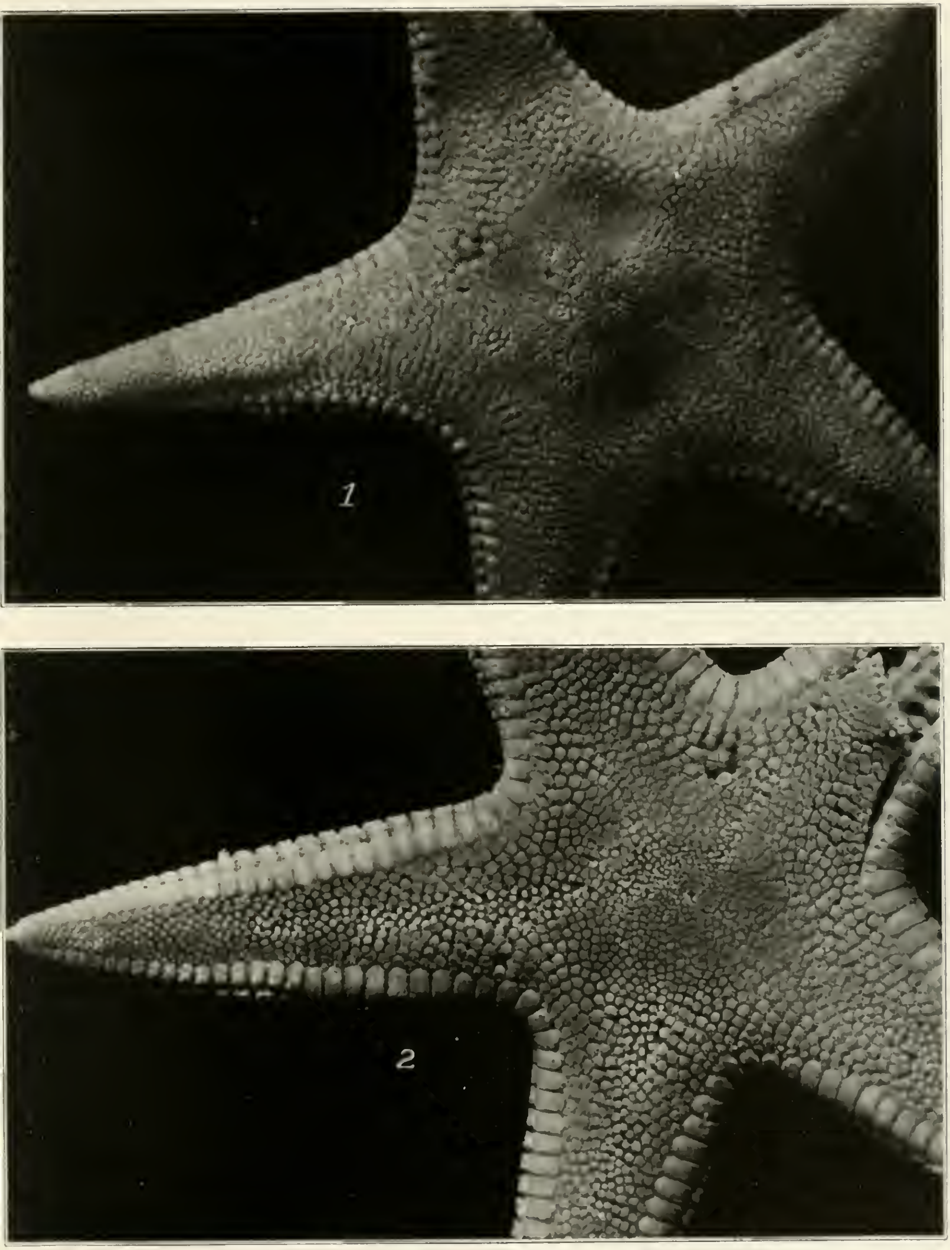
1, 2. Astropecten californicus. 3, 4. Astropecten ornatissimus

For explanation of plate see page 91



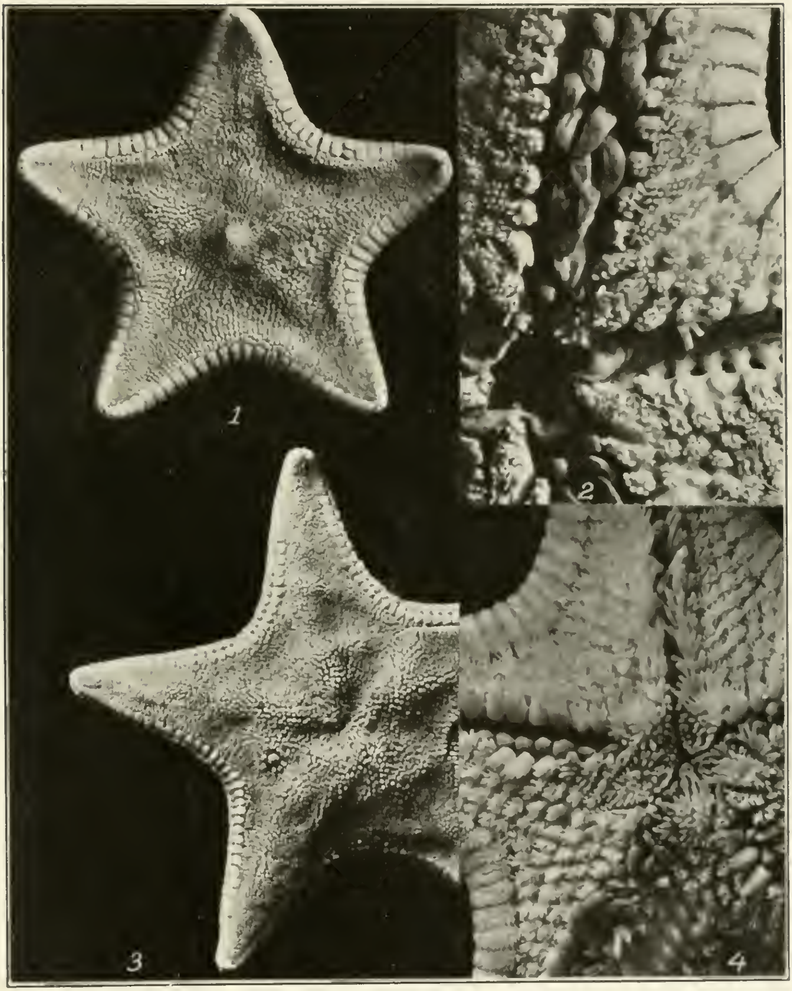
1. Astropecten californicus. 2. A. ornatissimus. 3, 6. A. armatus. 4. Leptychaster anomalus.
5, 7. Psilaster pectinatus.

For explanation of plate see page 391.



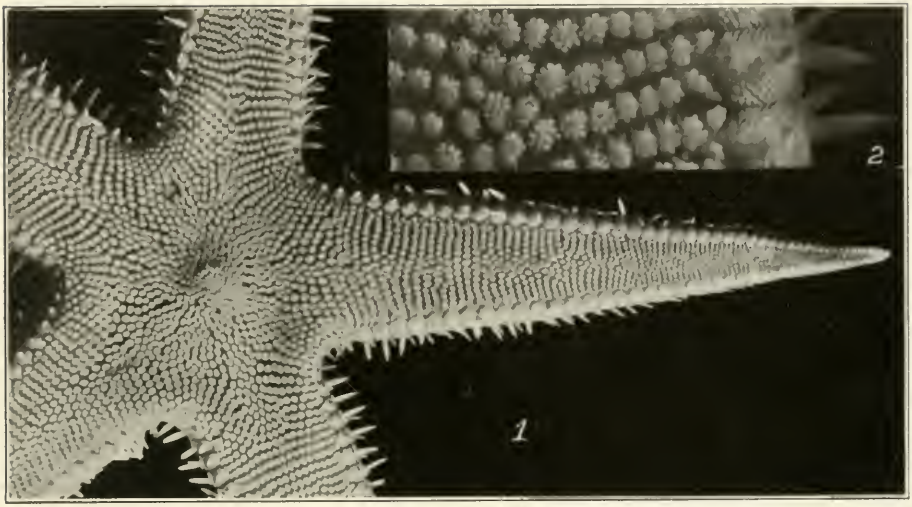
1. Leptychaster arcticus. 2. L. pacificus.

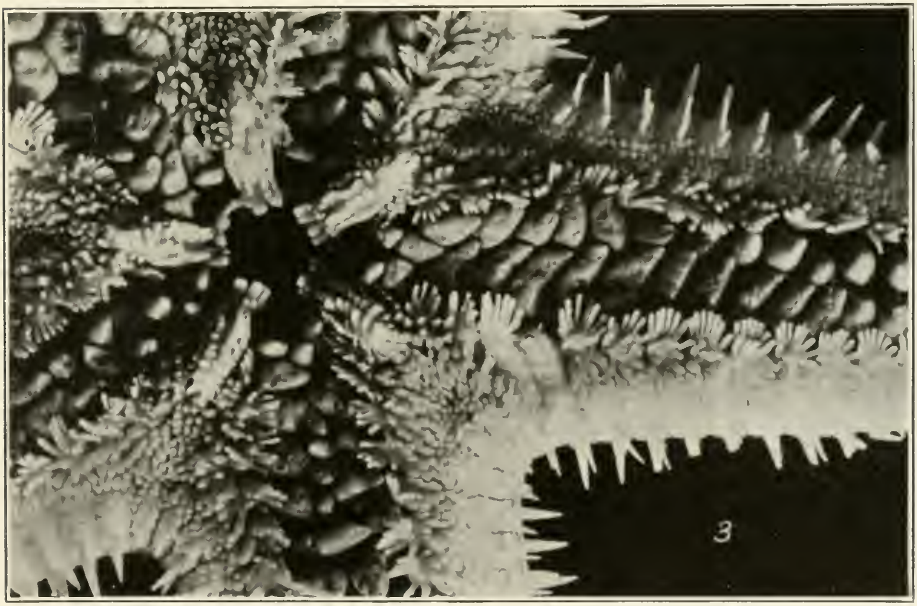
For explanation of plate see page 391.



1. LEPTYCHASTER ANOMALUS. 2. L. PACIFICUS 3. L. PROPINQUUS. 4 L. ARCTICUS.

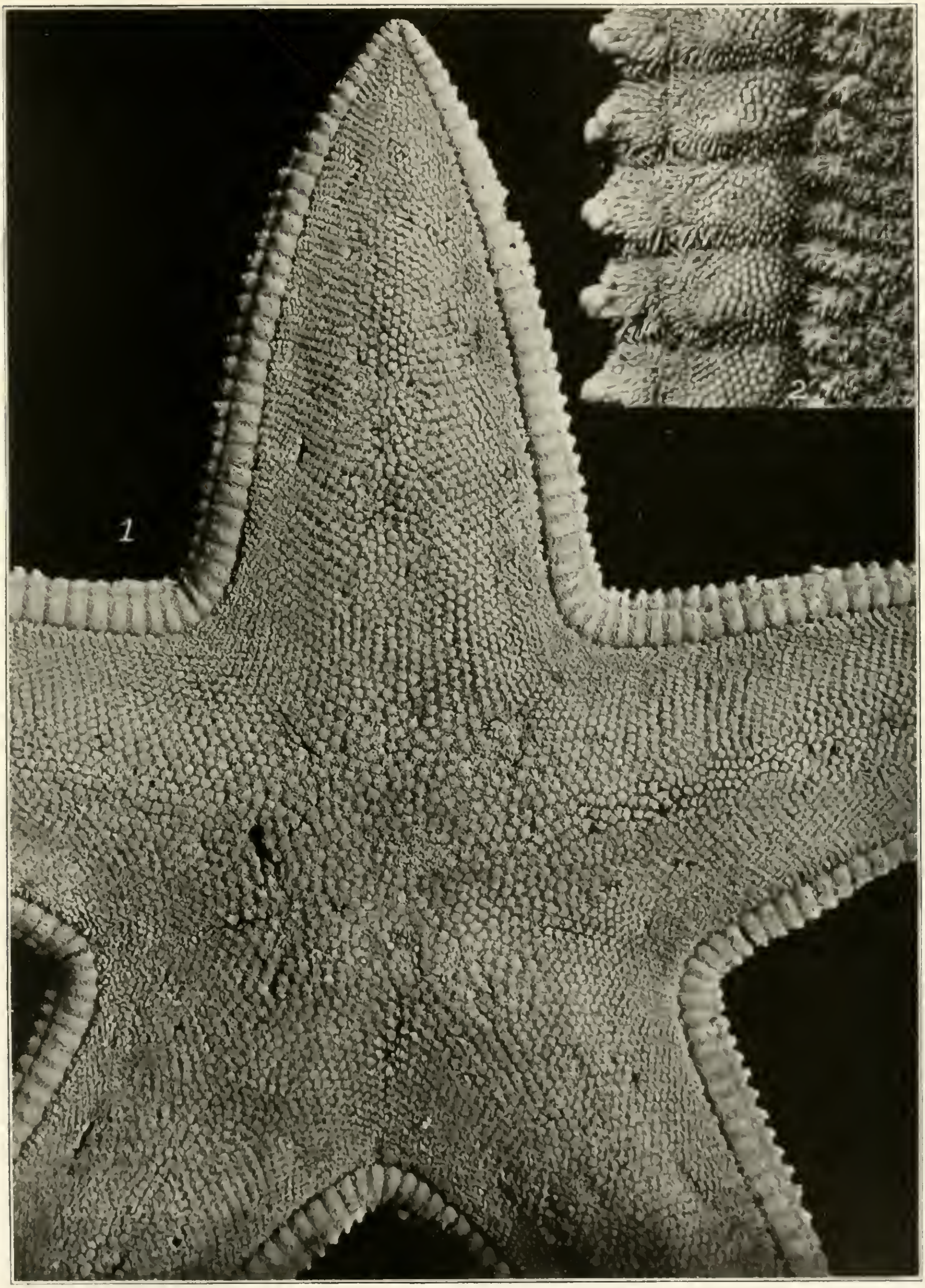
FOR EXPLANATION OF PLATE SEE PAGE 392.





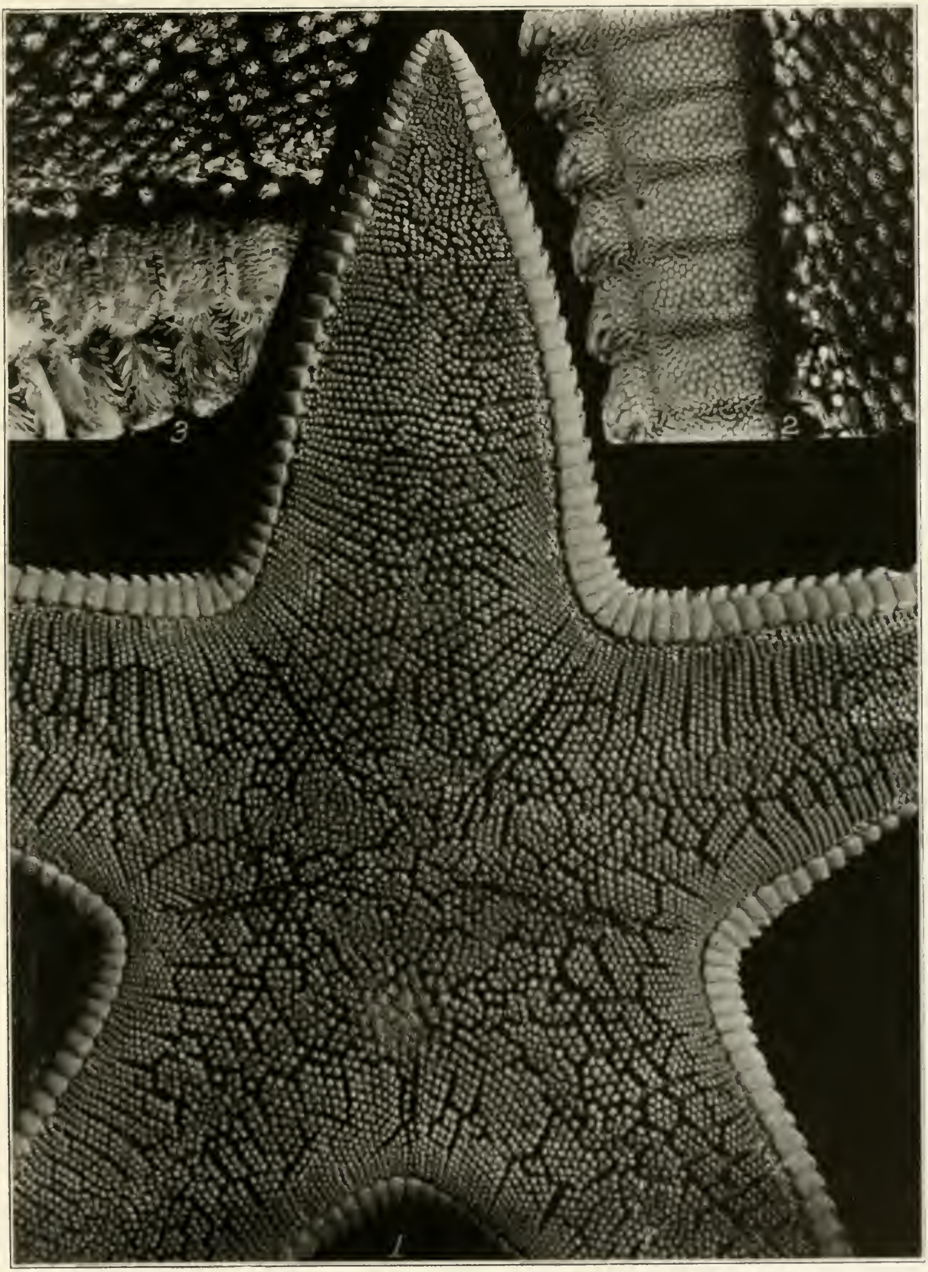
PSILASTER PECTINATUS.

FOR EXPLANATION OF PLATE SEE PAGE 392



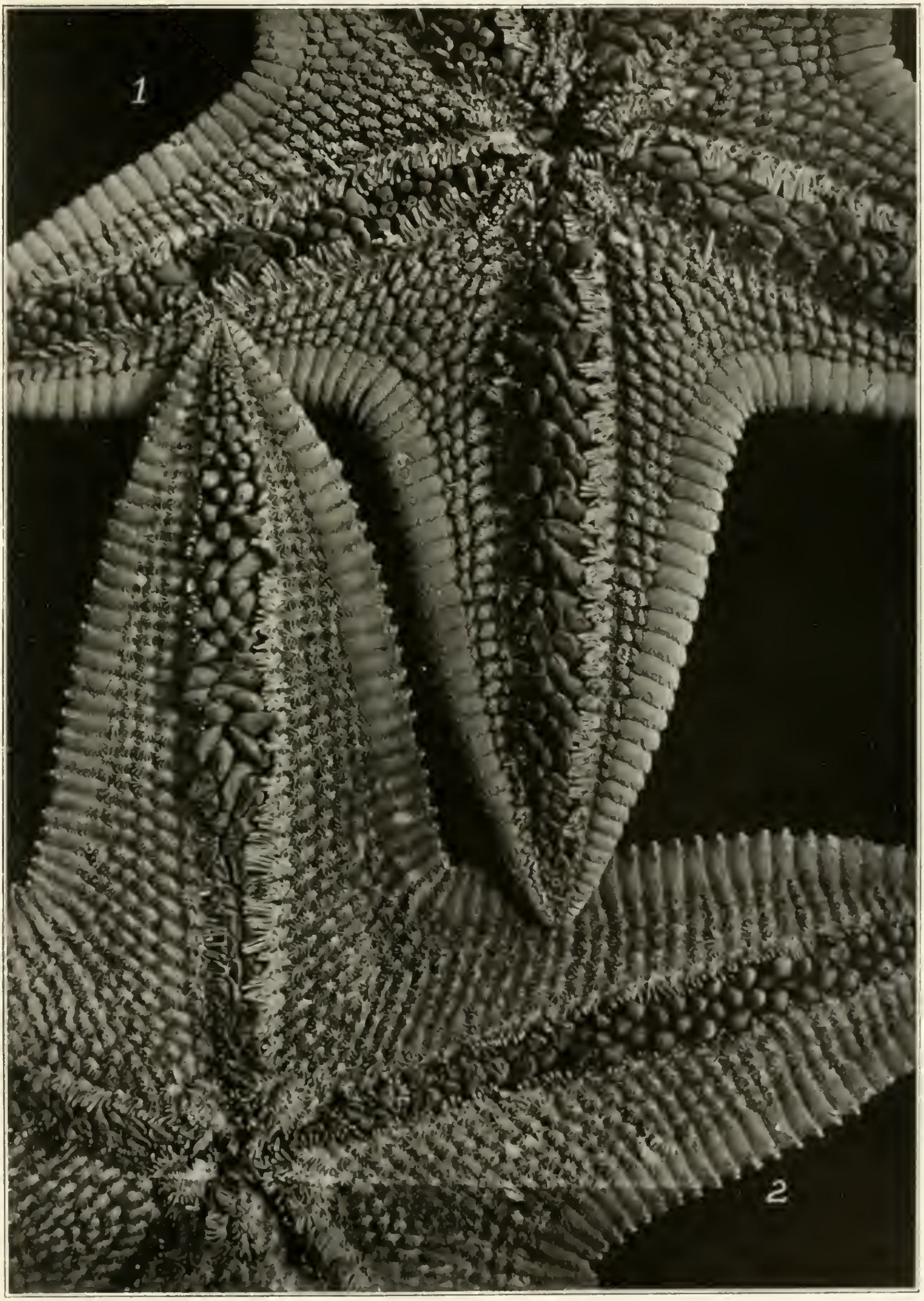
DIPSACASTER EXIMIUS.

For explanation of plate see page 39[illegible]



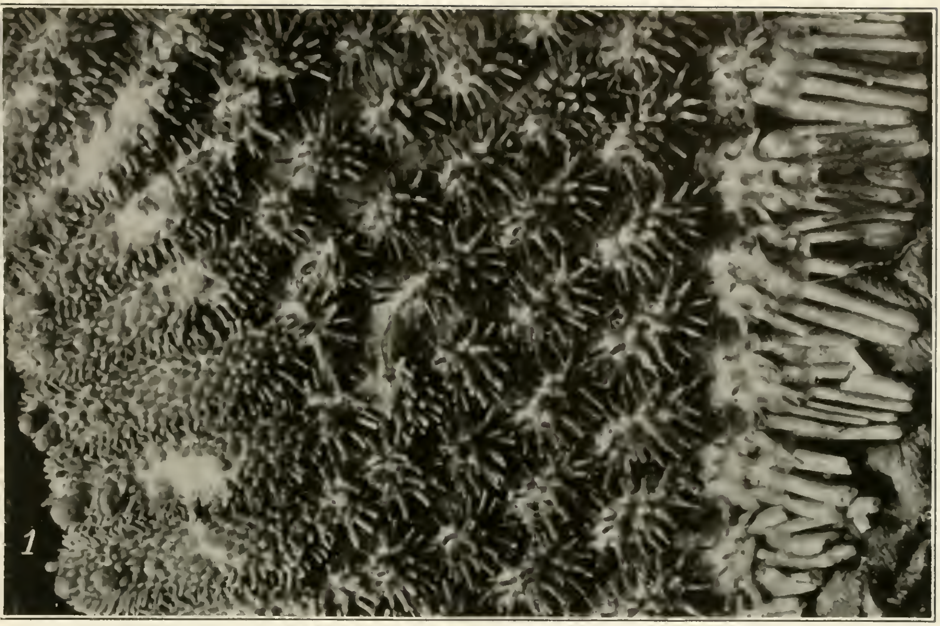
1, 2. Dipsacaster borealis. 3. D. lætmophilus

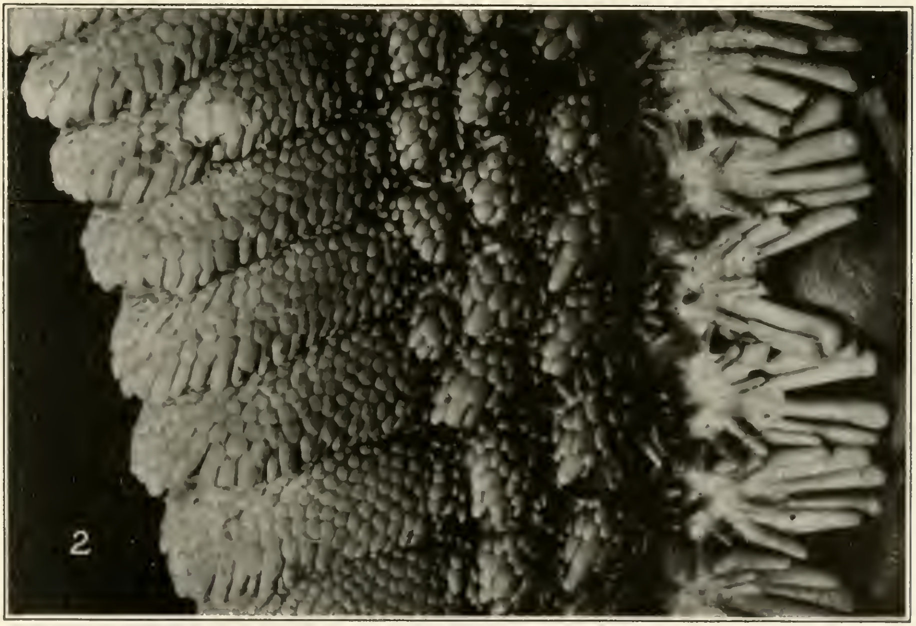
For explanation of plate see page 392



1. Dipsacaster borealis. 2. D. eximius

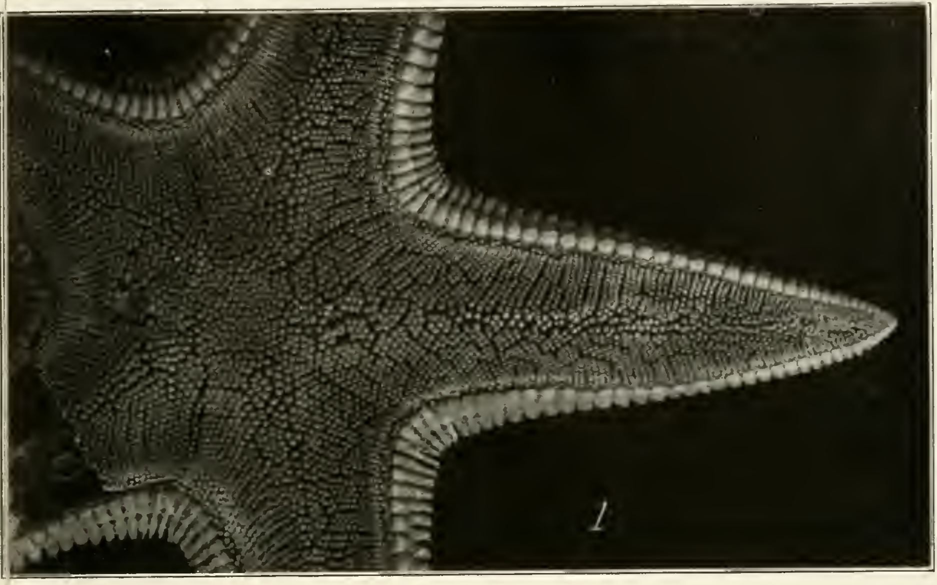
For explanation of plate see page 392



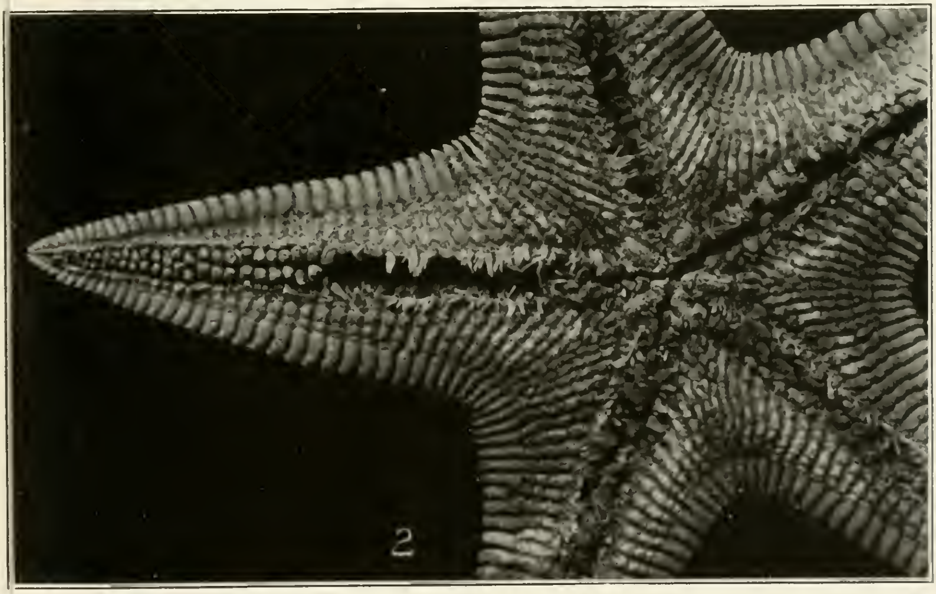


1. Dipsacaster eximius. 2. D. borealis.

For explanation of plate see page 392.



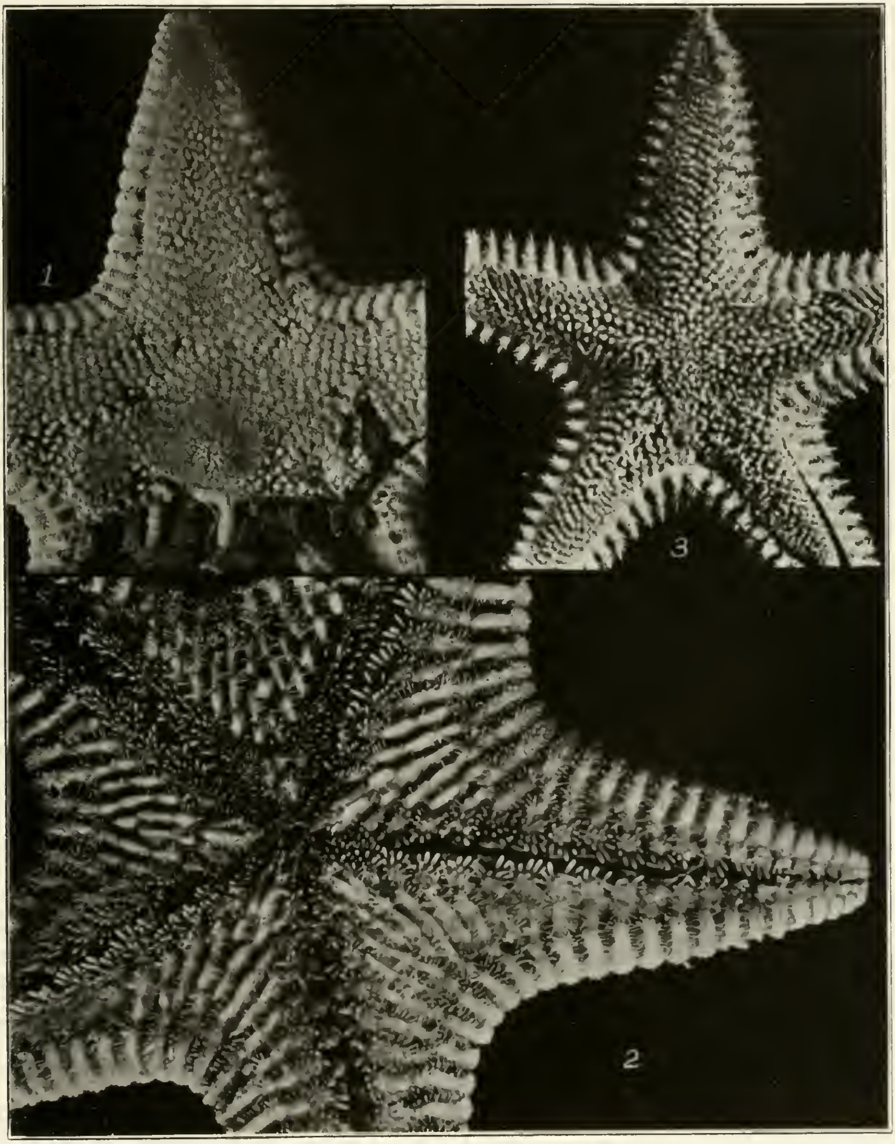
1



2

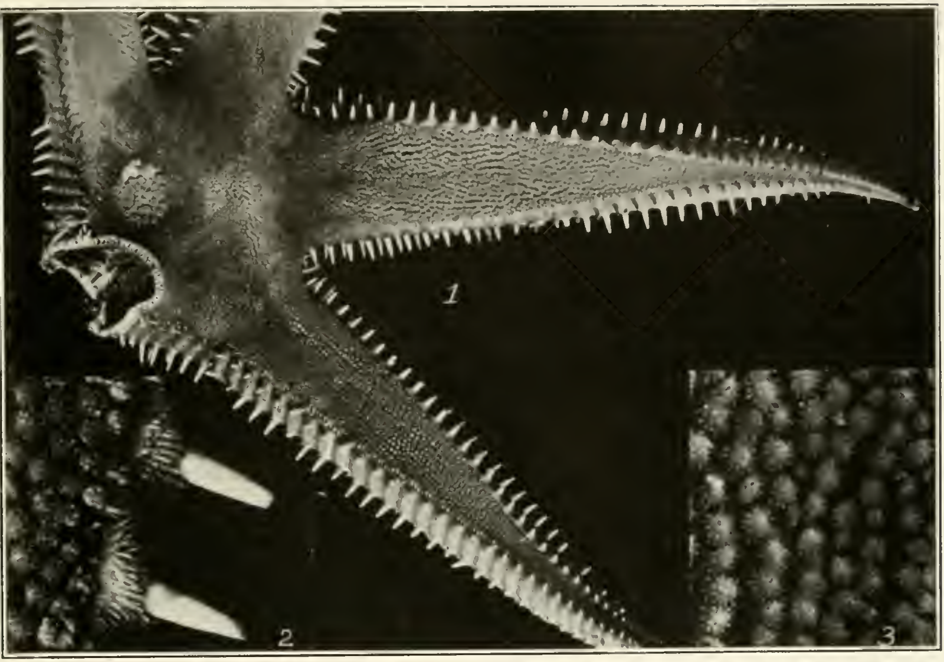
DIPSACASTER LÆTMOPHILUS.

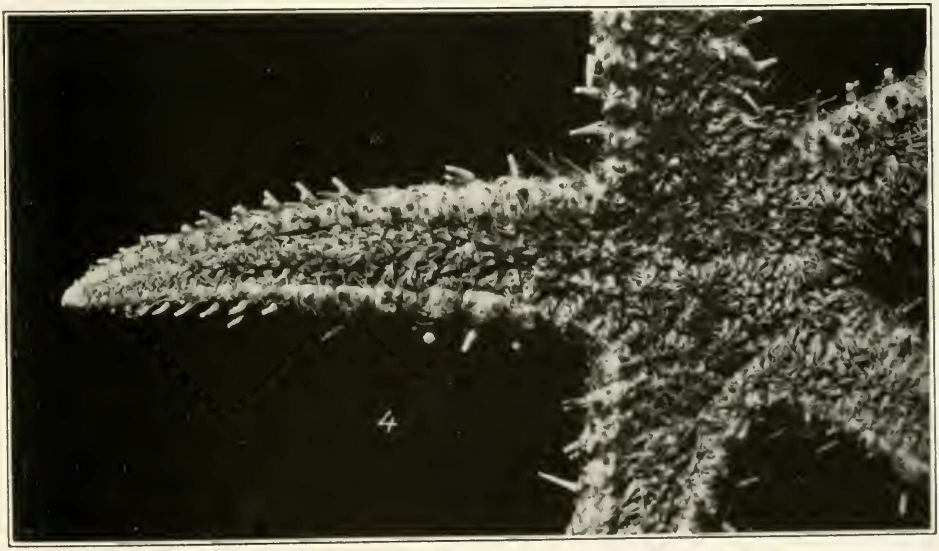
FOR EXPLANATION OF PLATE SEE PAGE 392.



1, 2. Dipsacaster anoplus. 3. D. eximius (young).

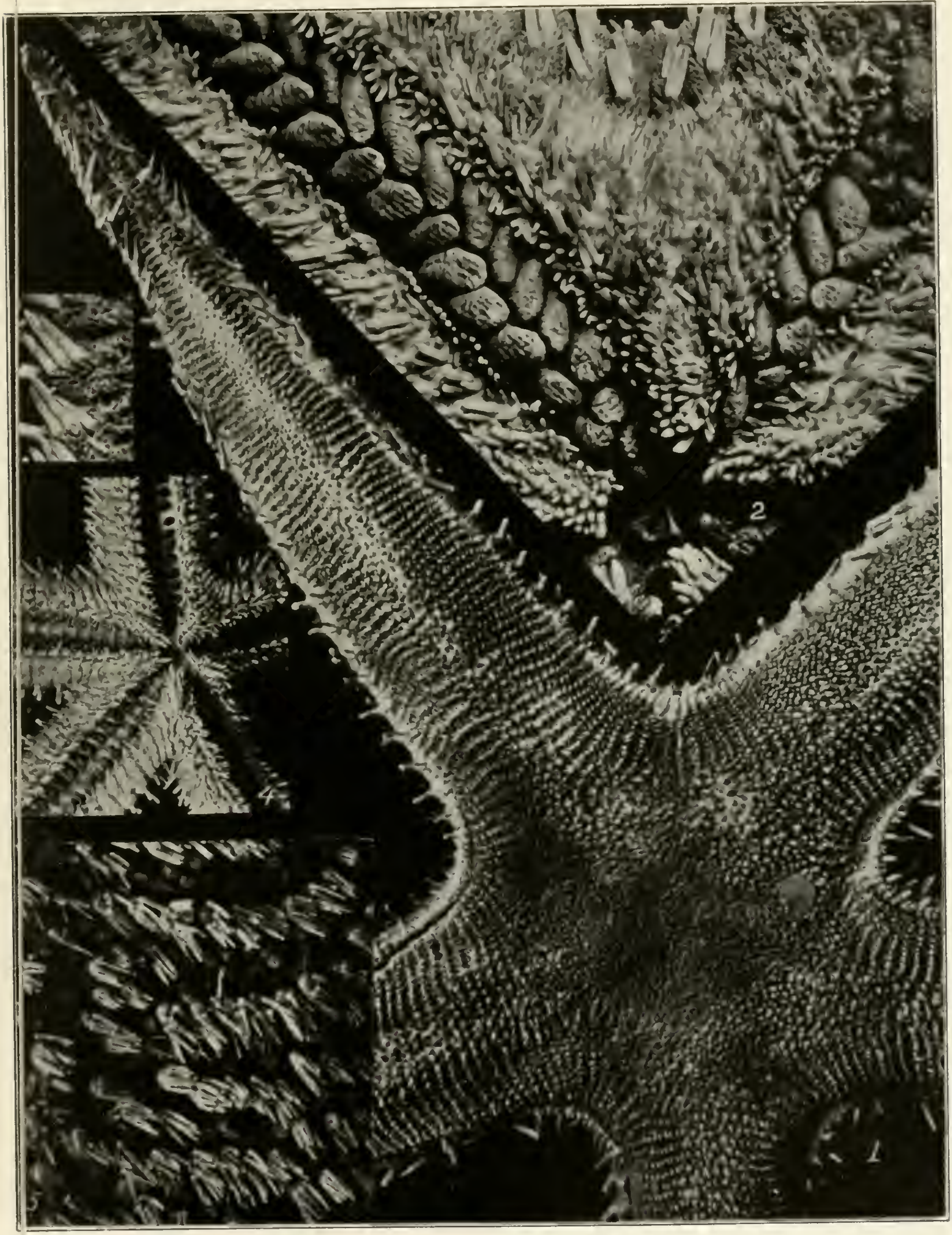
For explanation of plate see page 392.





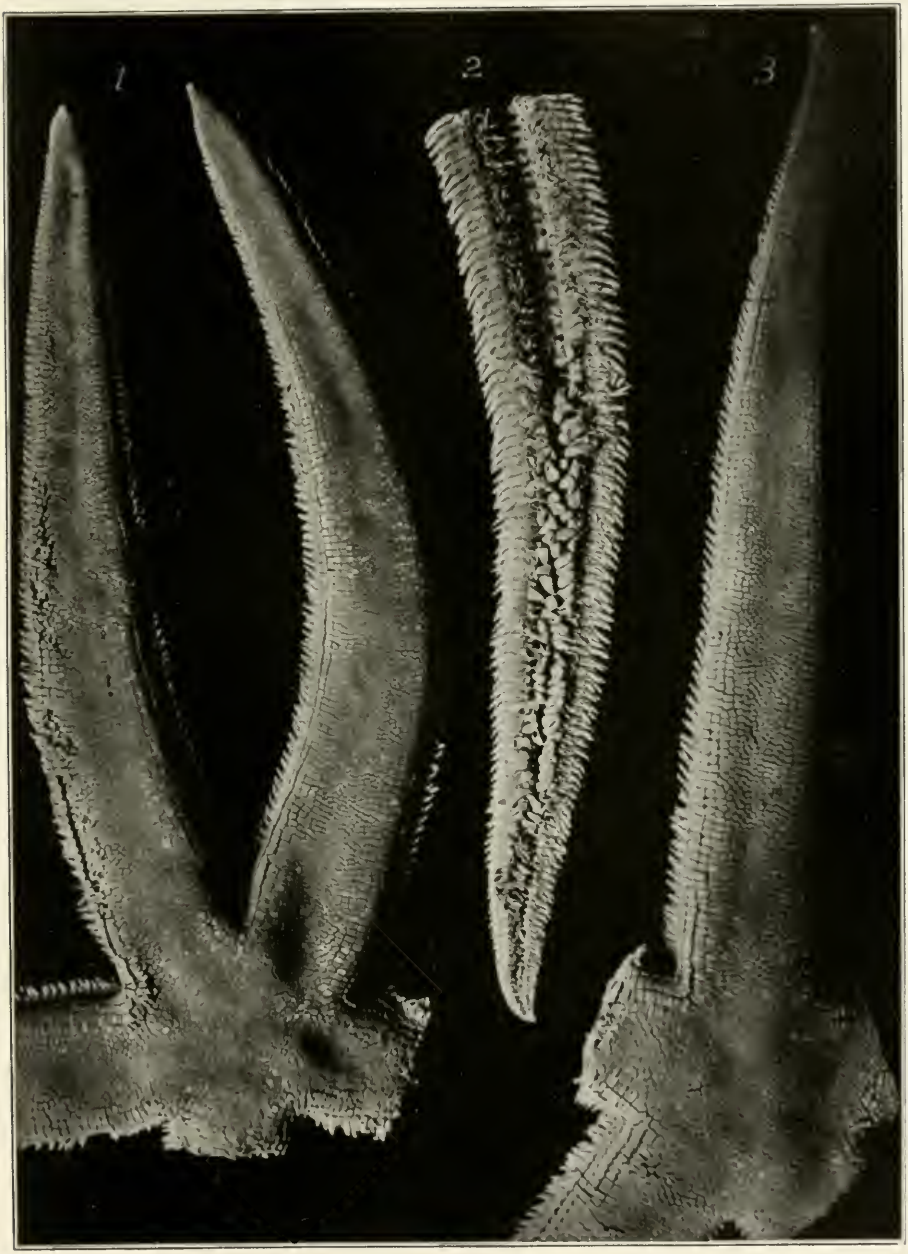
1-3. DYTASTER GILBERTI. 4. THRISSACANTHIAS PENICILLATUS.

FOR EXPLANATION OF PLATE SEE PAGE 392.



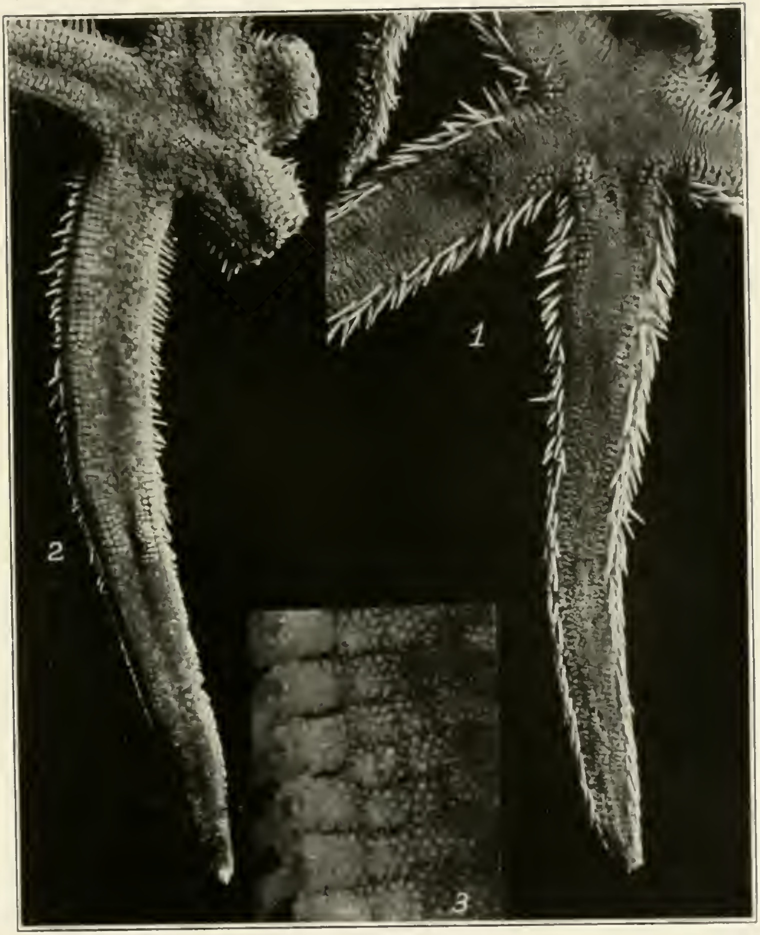
THRISSACANTHIAS PENICILLATUS.

FOR EXPLANATION OF PLATE SEE PAGE 392.



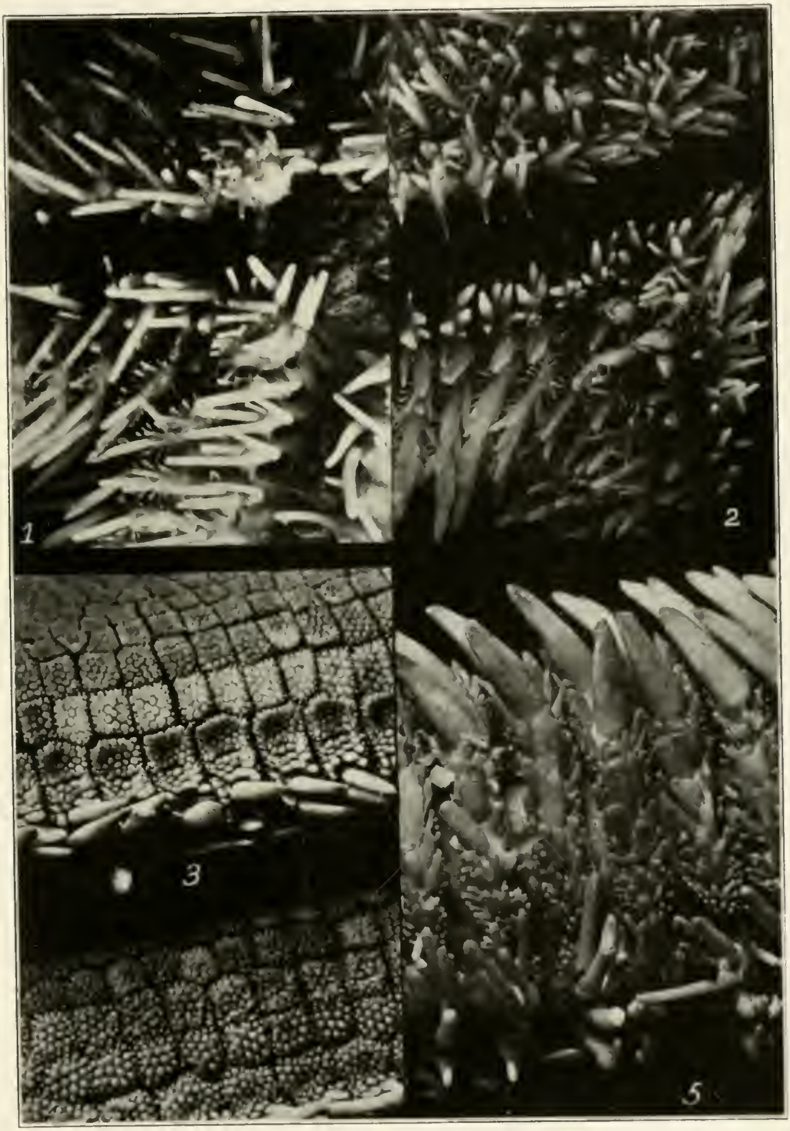
LUIDIA FOLIOLATA

FOR EXPLANATION OF PLATE SEE PAGE [illegible]



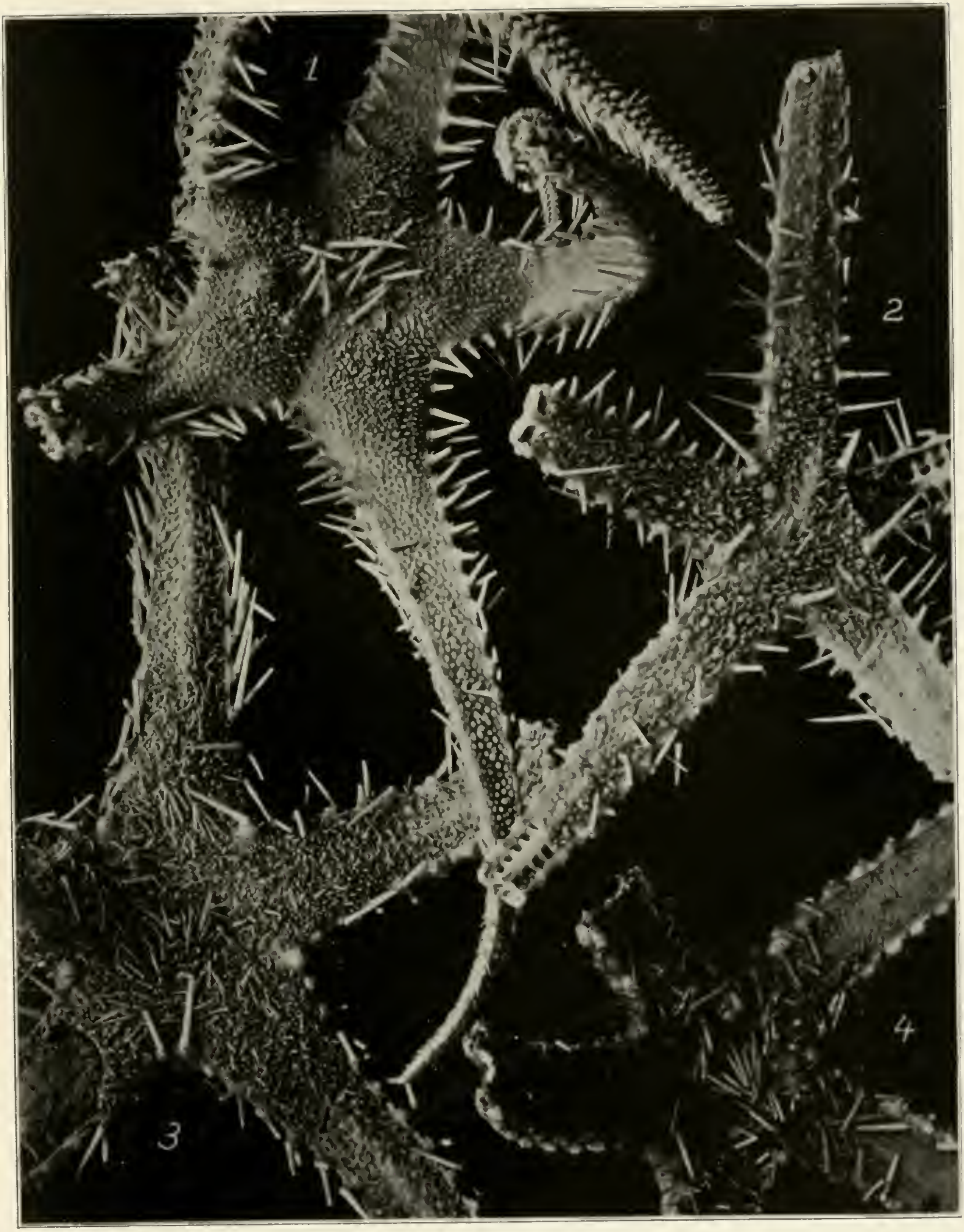
1. Luidia asthenosoma. 2, 3. L. ludwigi.

For explanation of plate see page 393



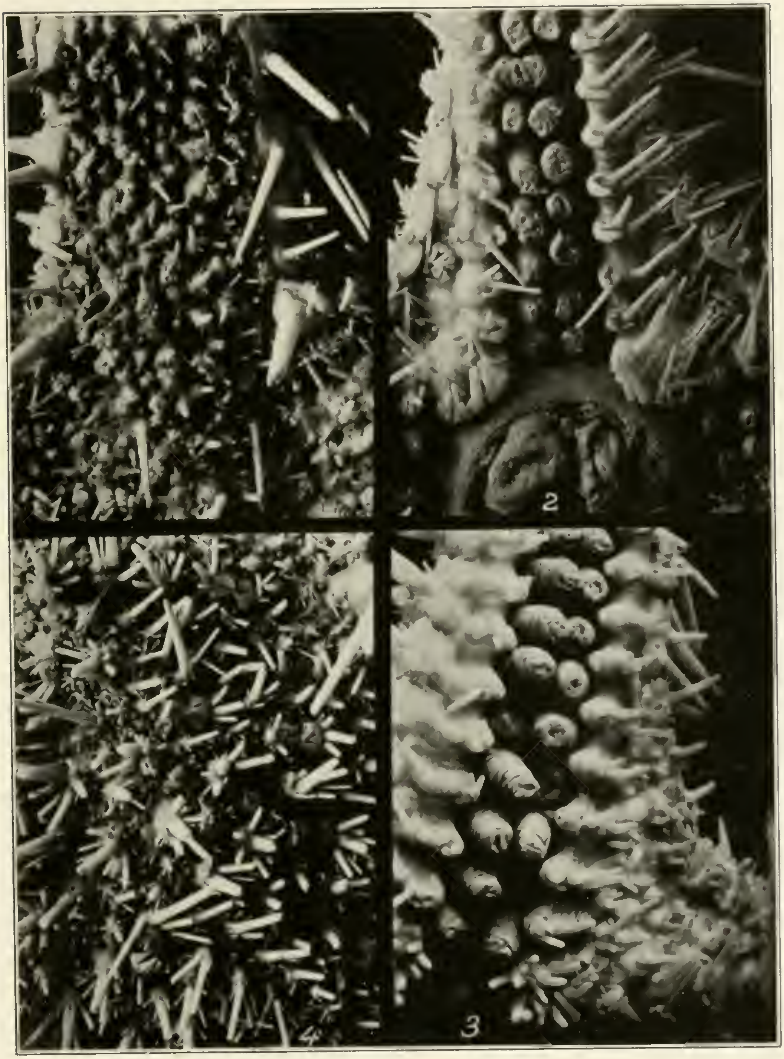
1. LUIDIA ASTHENOSOMA. 2. L. LUDWIGI. 3-5. L. FOLIOLATA.

FOR EXPLANATION OF PLATE SEE PAGE 393



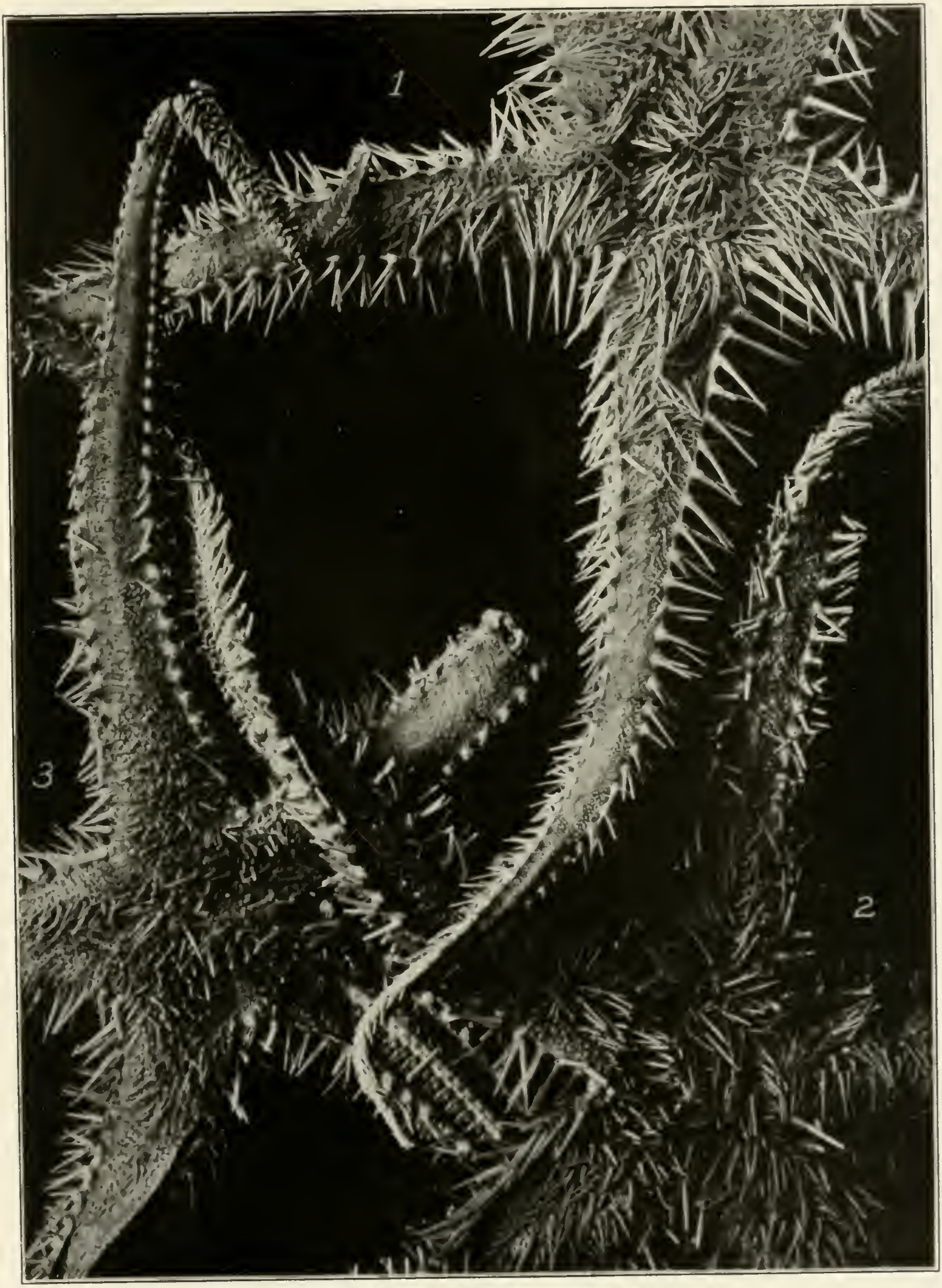
1. BENTHOPECTEN MUTABILIS. 2, 3. B. ACANTHONOTUS 4. B. CLAVIGER

FOR EXPLANATION OF PLATE SEE PAGE 393.



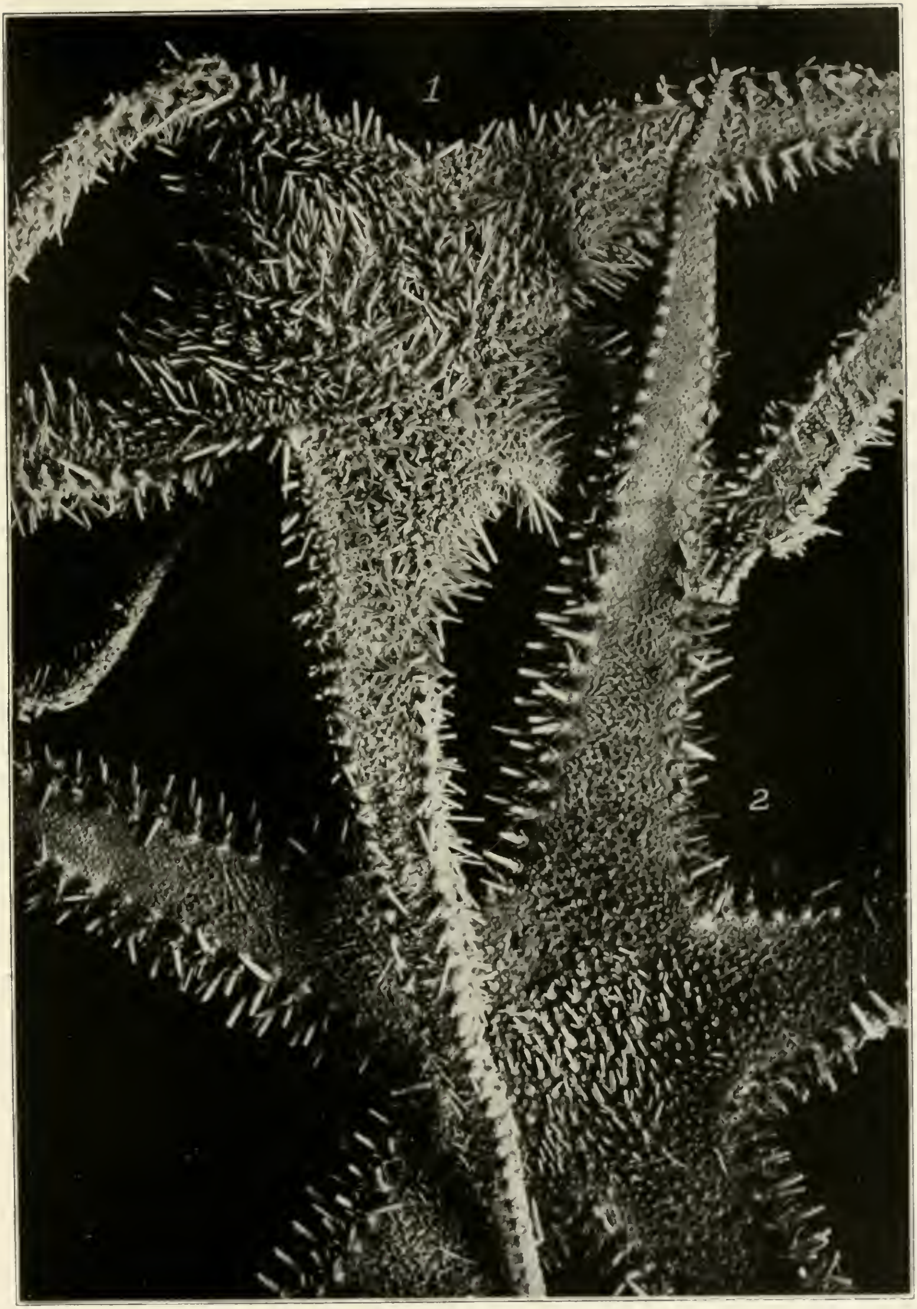
1, 2. BENTHOPECTEN ACANTHONOTUS. 3. B. MUTABILIS. 4. NEARCHASTER PEDICELLARIS.

FOR EXPLANATION OF PLATE SEE PAGE 393.



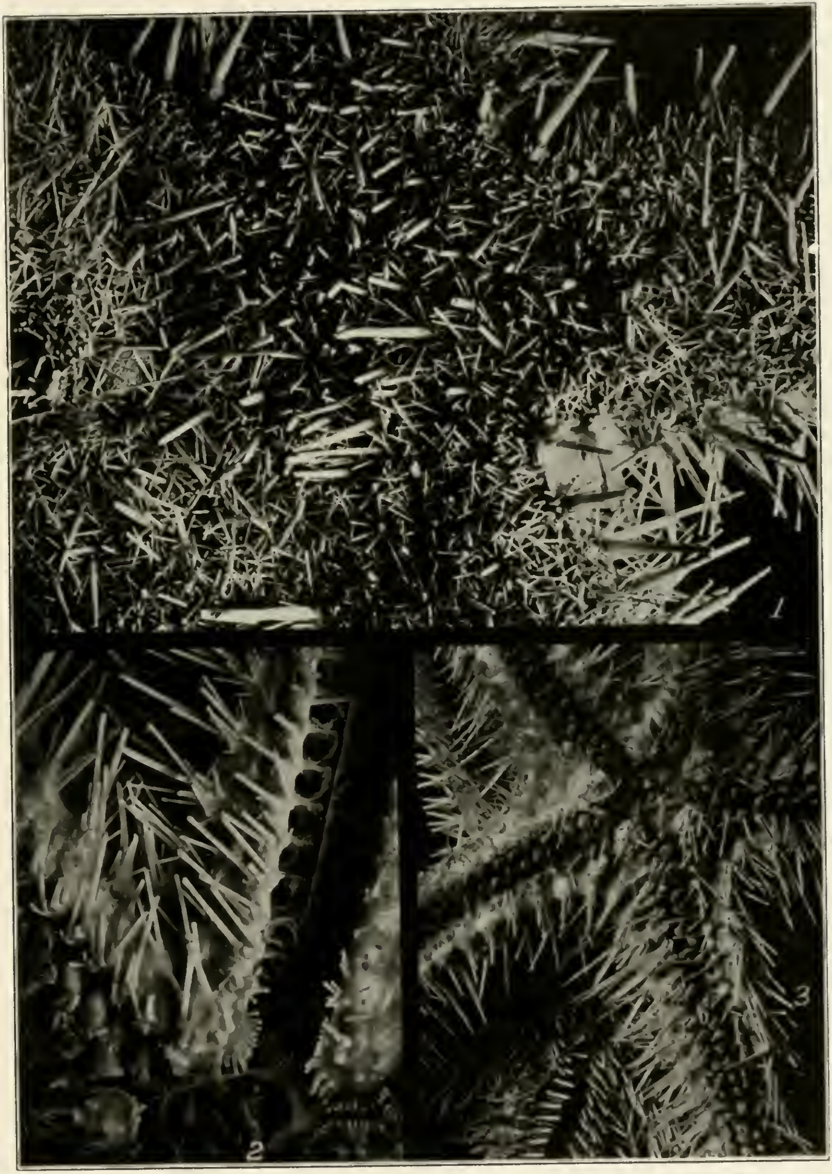
1. Nearchaster aciculosus. 2. N. variabilis. 3. Myonotus intermedius.

For explanation of plate see page 393



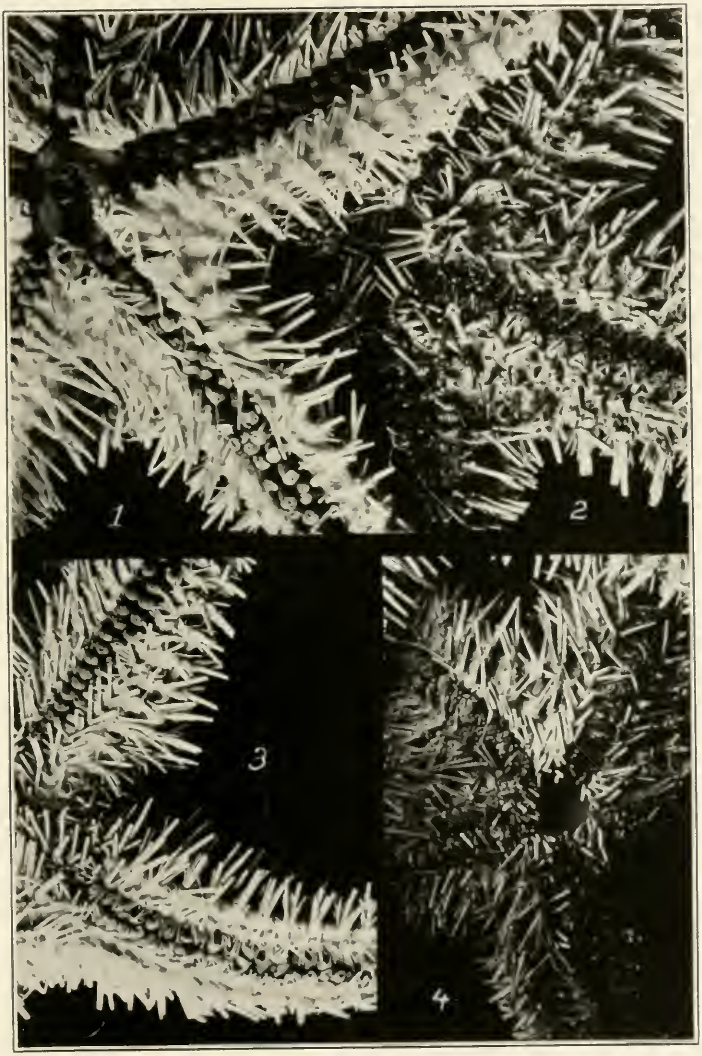
1. NEARCHASTER PEDICELLARIS 2. LUIDIASTER DAWSONI.

FOR EXPLANATION OF PLATE SEE PAGE 393.



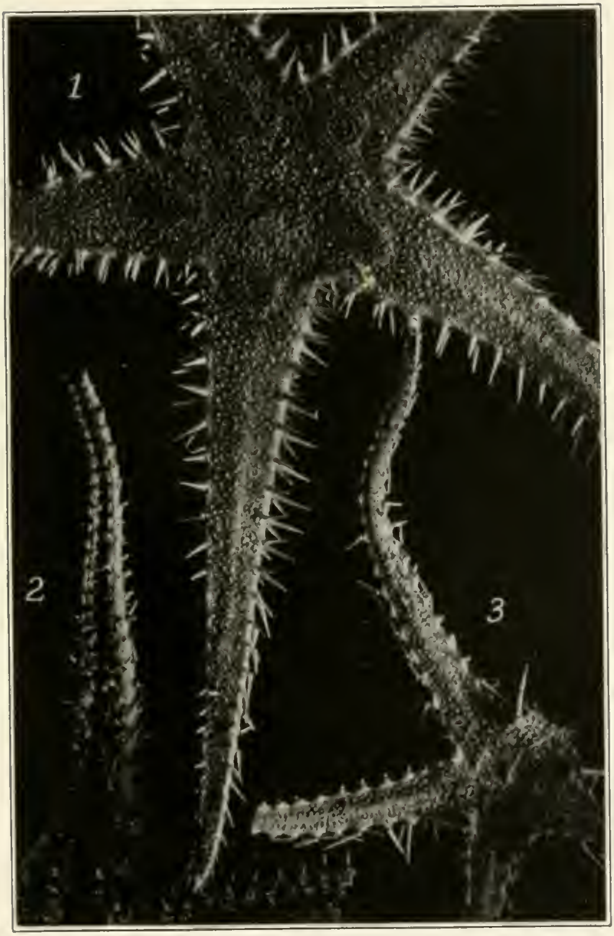
1, 2. Nearchaster aciculosus. 3. N. aciculosus (upper) and Luidiaster dawsoni (lower).

For explanation of plate see page 393.



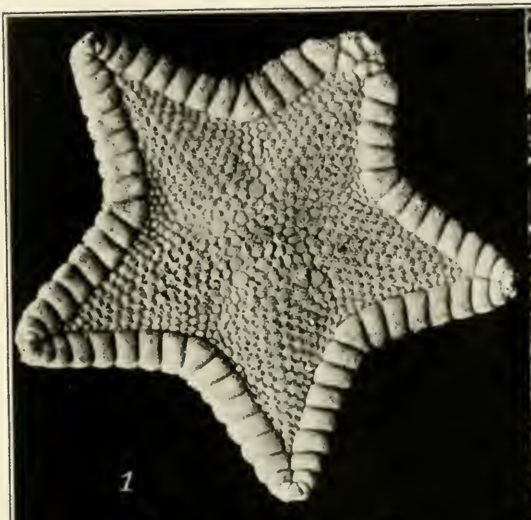
1. Myonotus intermedius. 2. Luidiaster dawsoni. 3. Nearchaster pedicellaris. 4. N. variabilis.

For explanation of plate see page 393.



1, 2. PECTINASTER AGASSIZI EVOPLUS. 3. BENTHOPECTEN ACANTHONOTUS, YOUNG.

FOR EXPLANATION OF PLATE SEE PAGE 343.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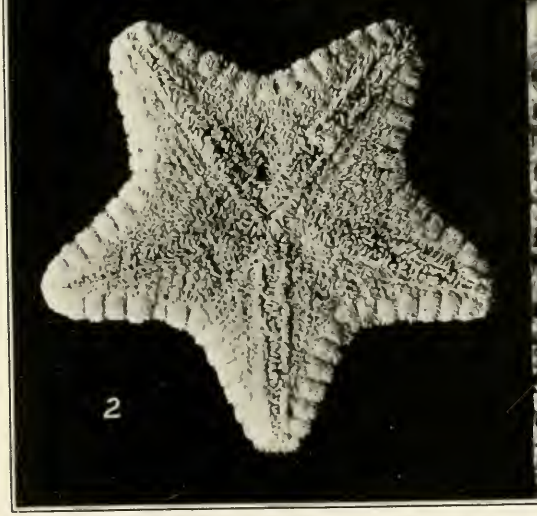
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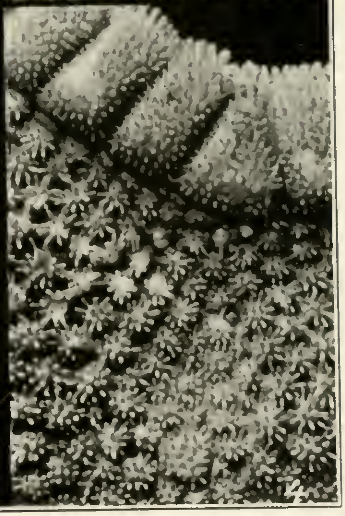
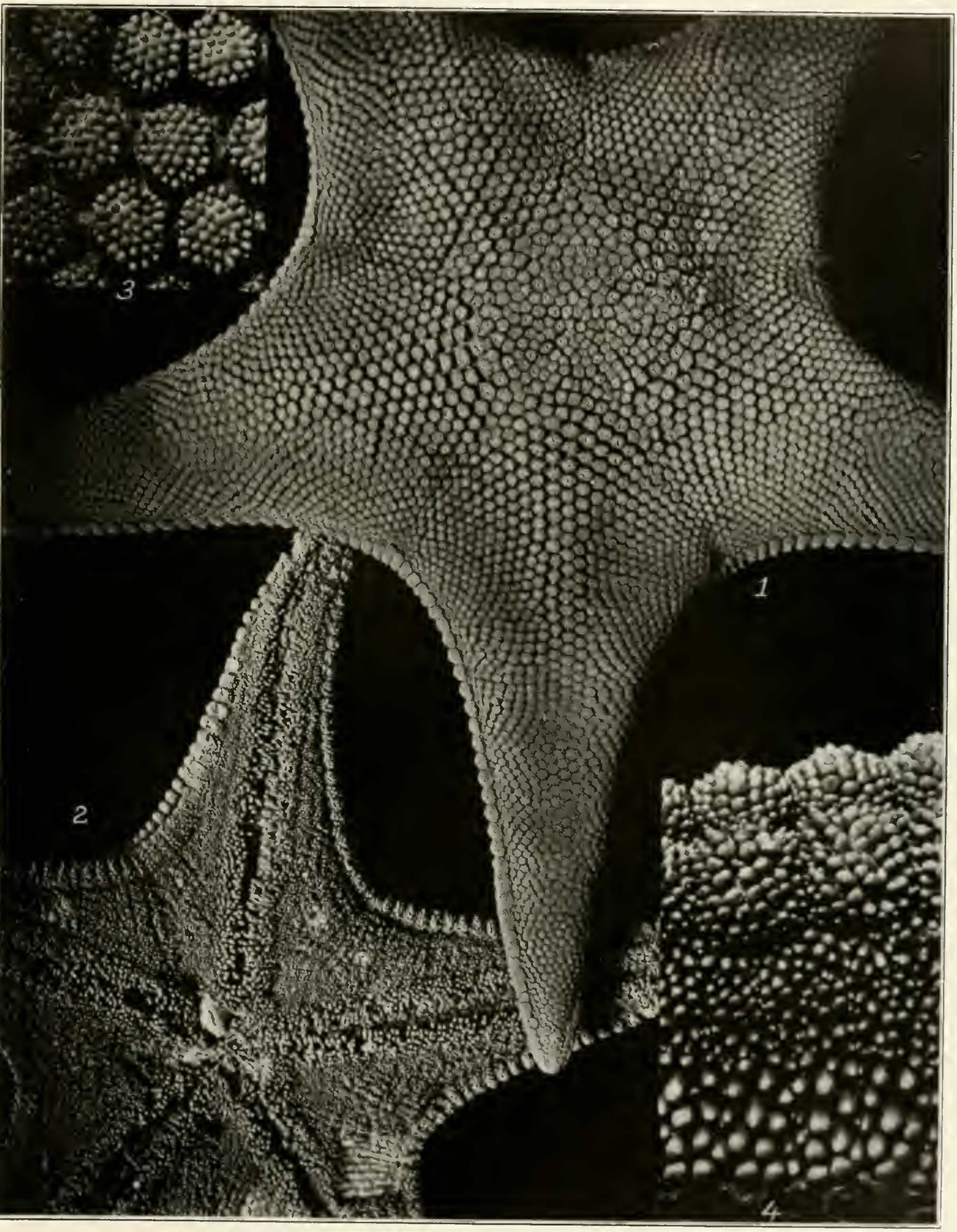

4

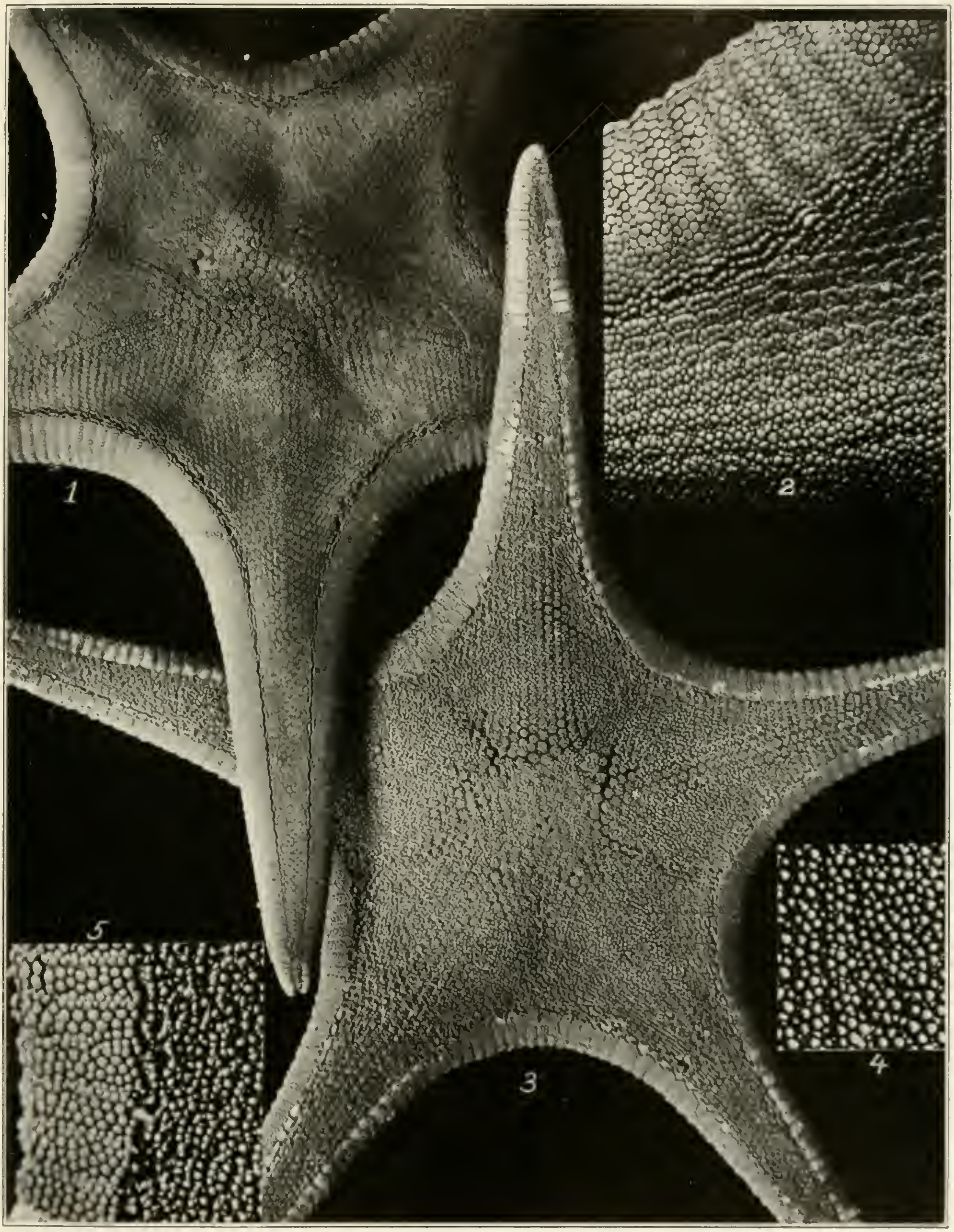
ODONTASTER CRASSUS.

For explanation of plate see page 393.



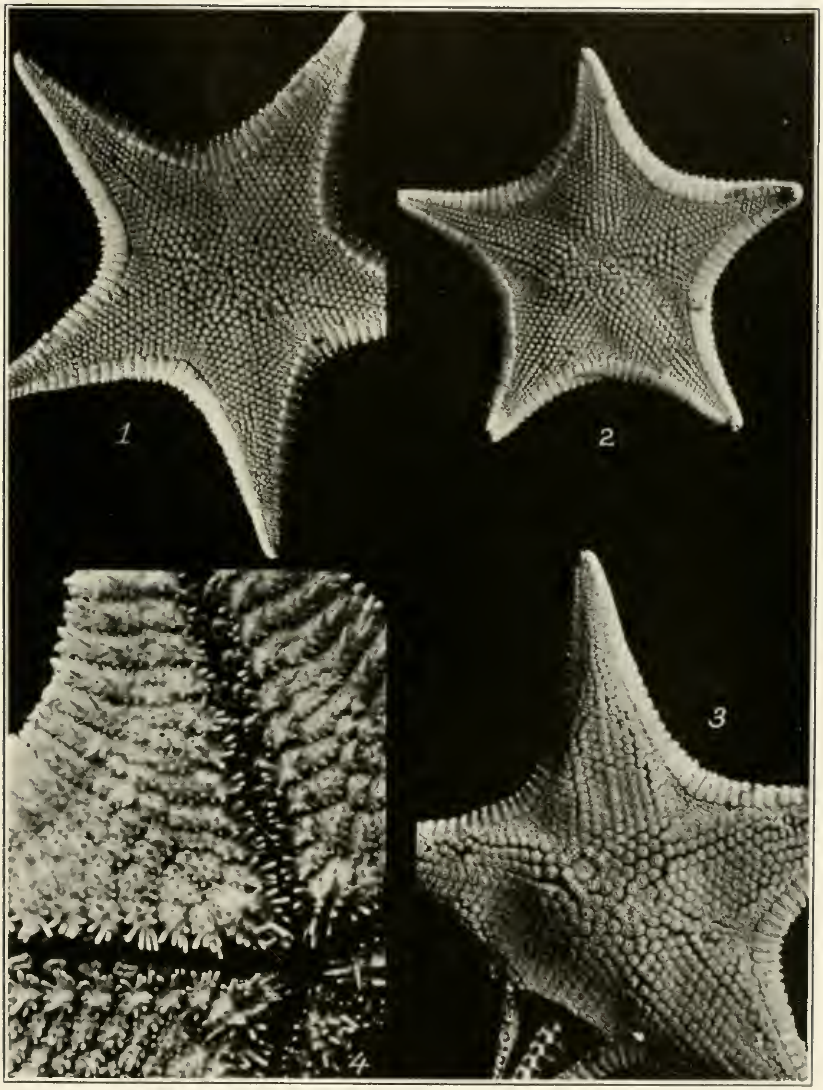
GEPHYREASTER SWIFTI

FOR EXPLANATION OF PLATE SEE PAGE 394.



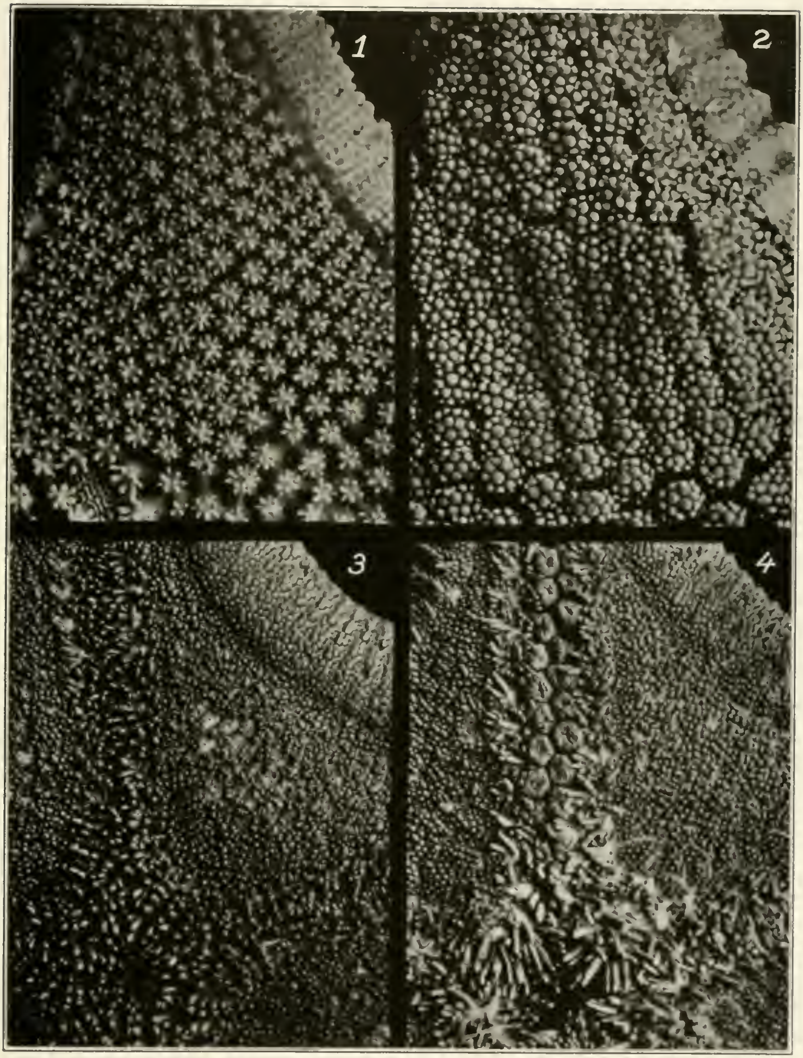
1, 2. PSEUDARCHASTER PARELII. 3–5. PS. PARELII ALASCENSIS.

For explanation of plate see page 394.



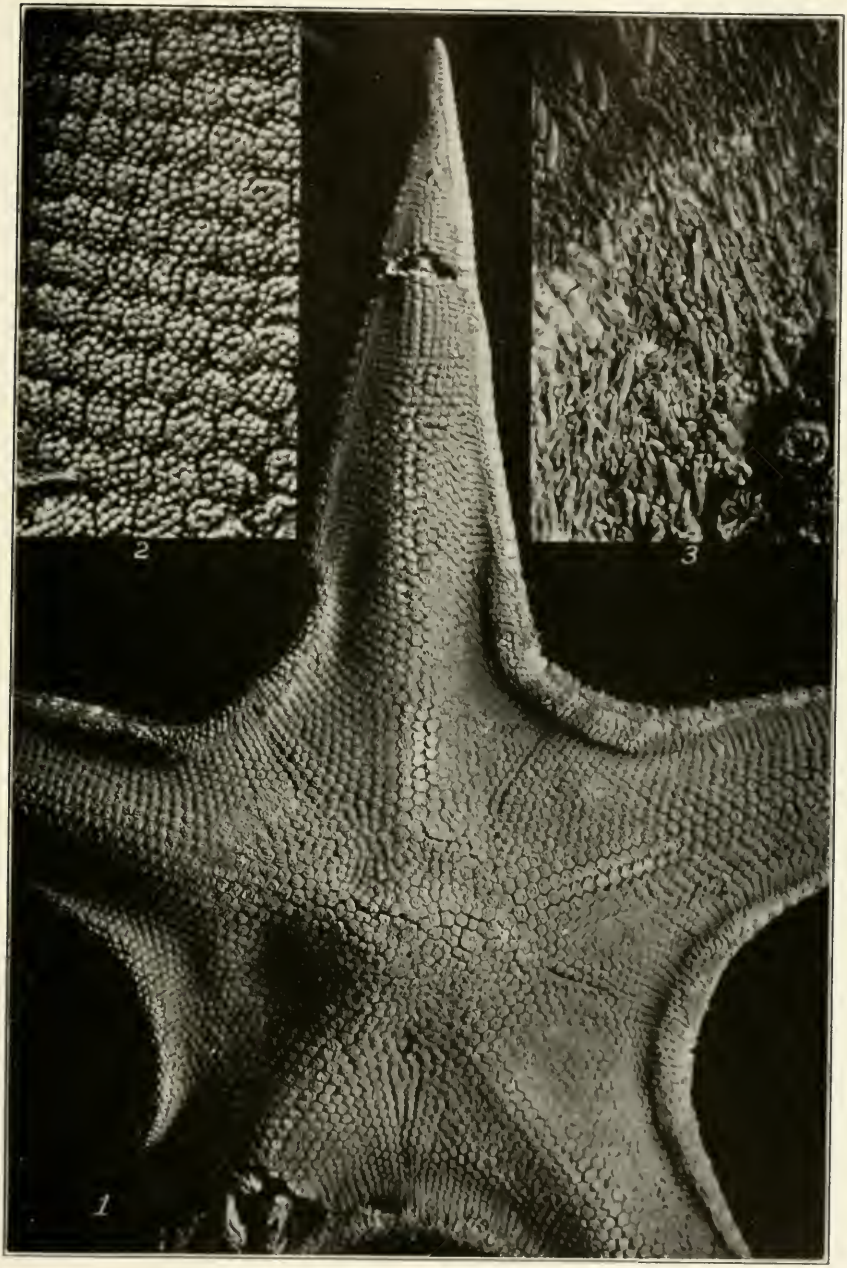
PSEUDARCHASTER PUSILLUS.

FOR EXPLANATION OF PLATE SEE PAGE 394.



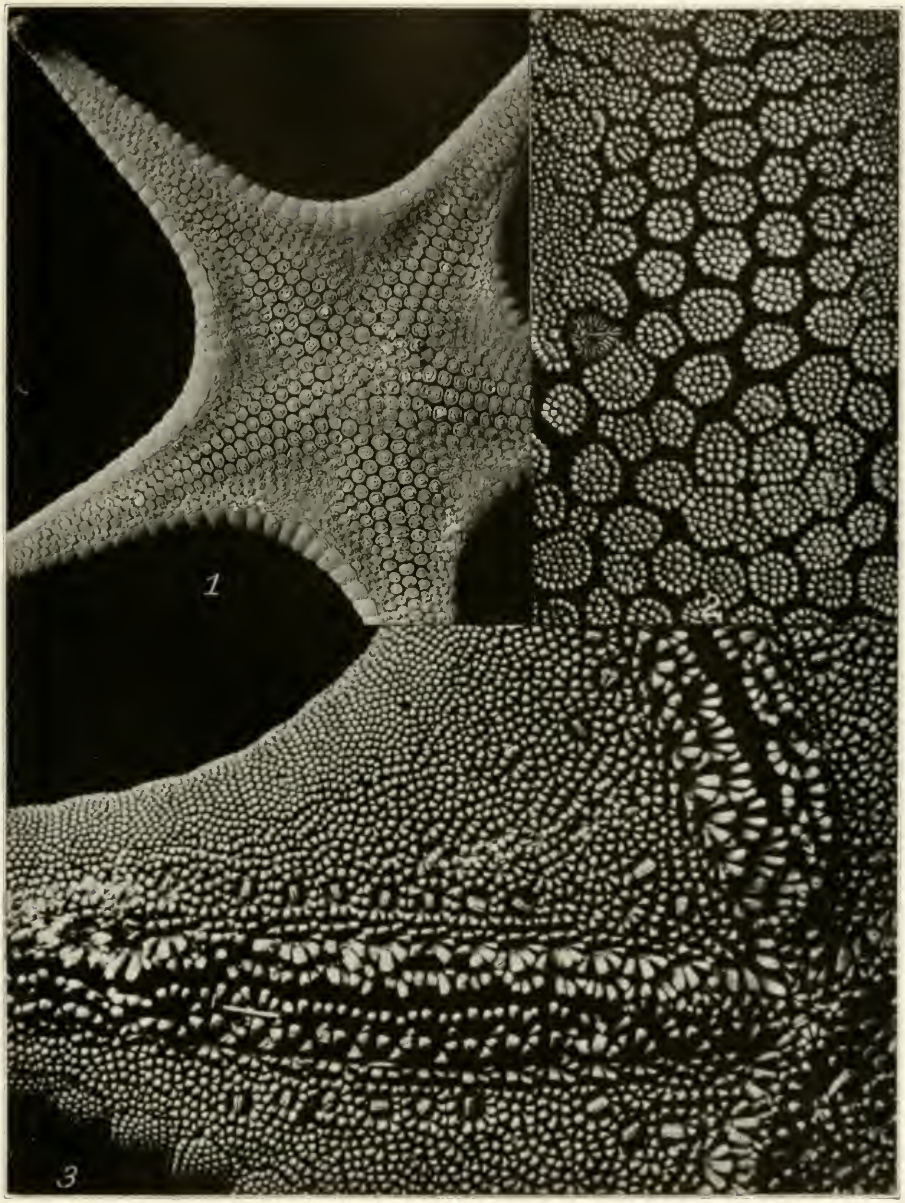
1, 2. PSEUDARCHASTER PUSILLUS. 3. PS. PARELII. 4. PS. PARELII ALASKENSIS.

FOR EXPLANATION OF PLATE SEE PAGE 394.



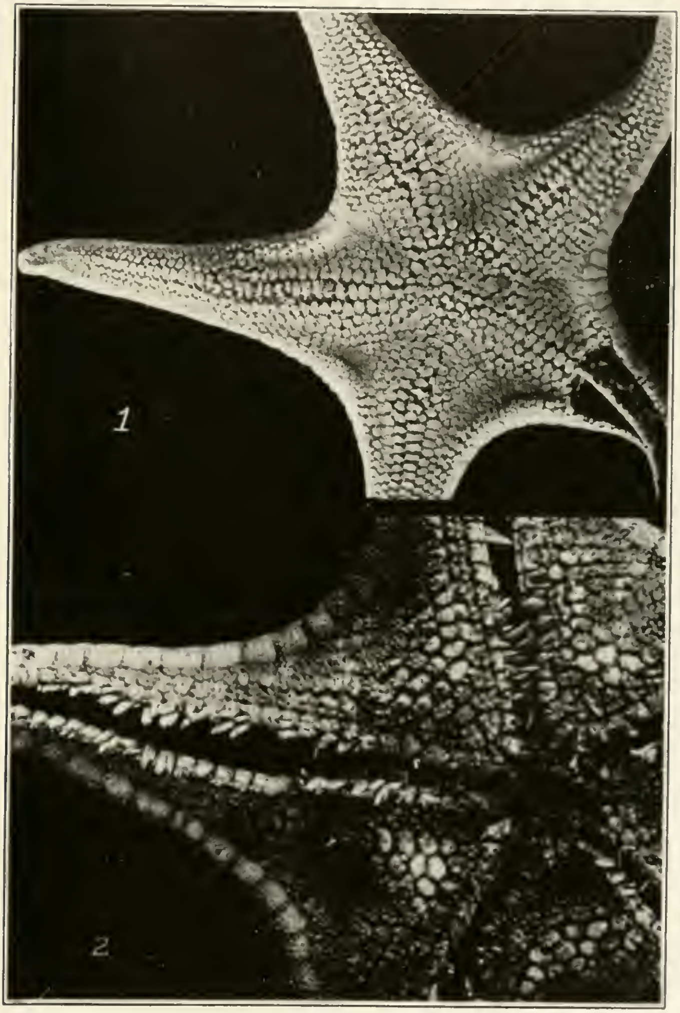
PSEUDARCHASTER DISSONUS.

FOR EXPLANATION OF PLATE SEE PAGE 394.



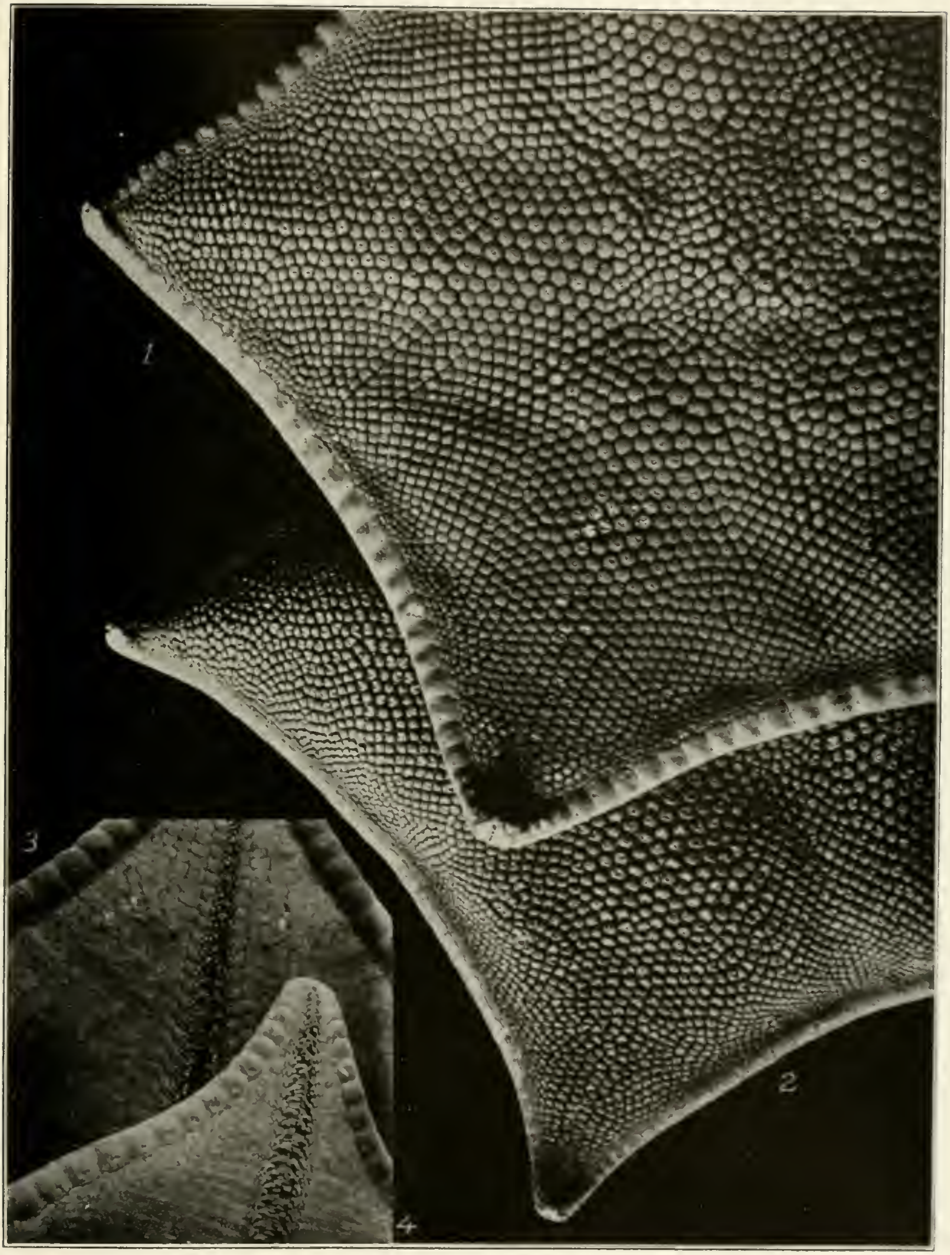
MEDIASTER ÆQUALIS.

For explanation of plate see page 394



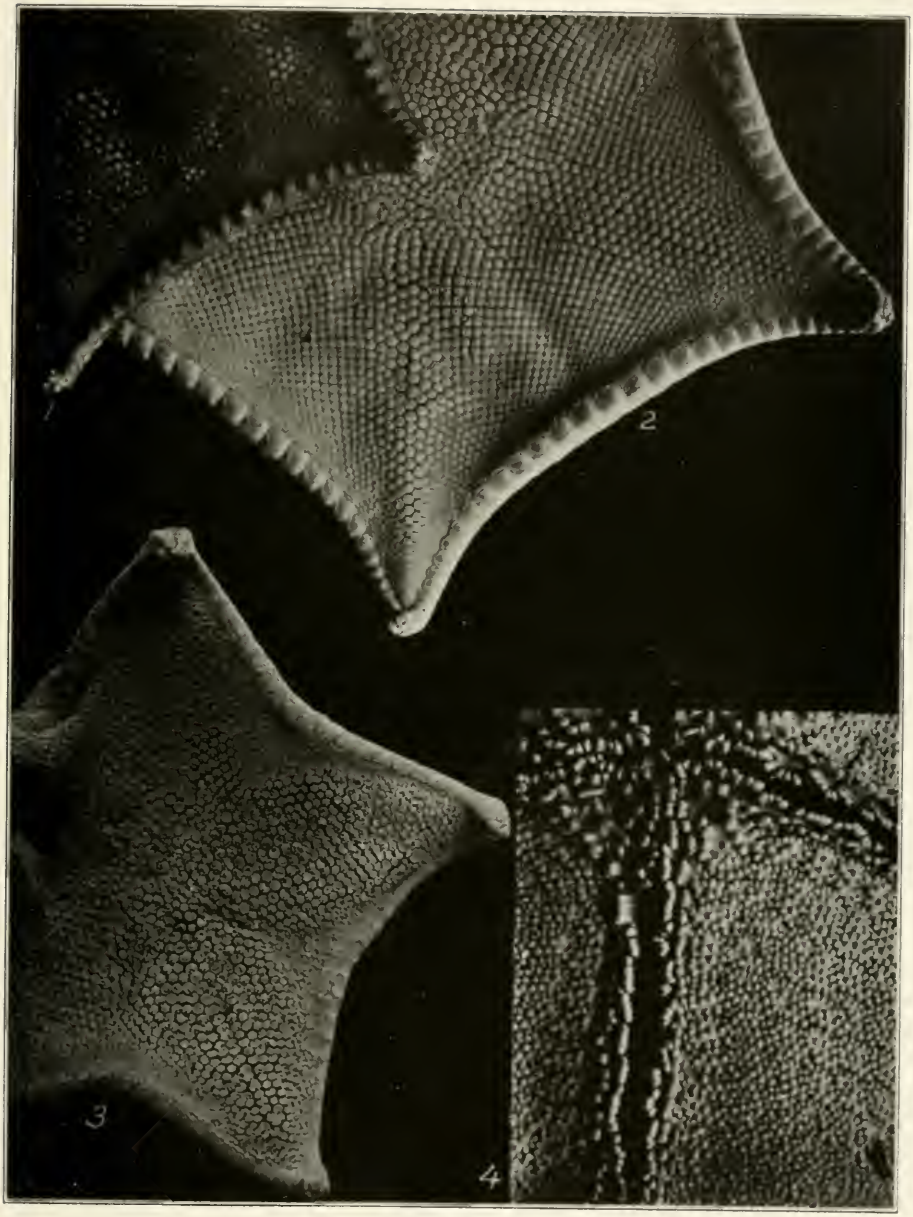
MEDIASTER TENELLUS

FOR EXPLANATION OF PLATE SEE PAGE 394



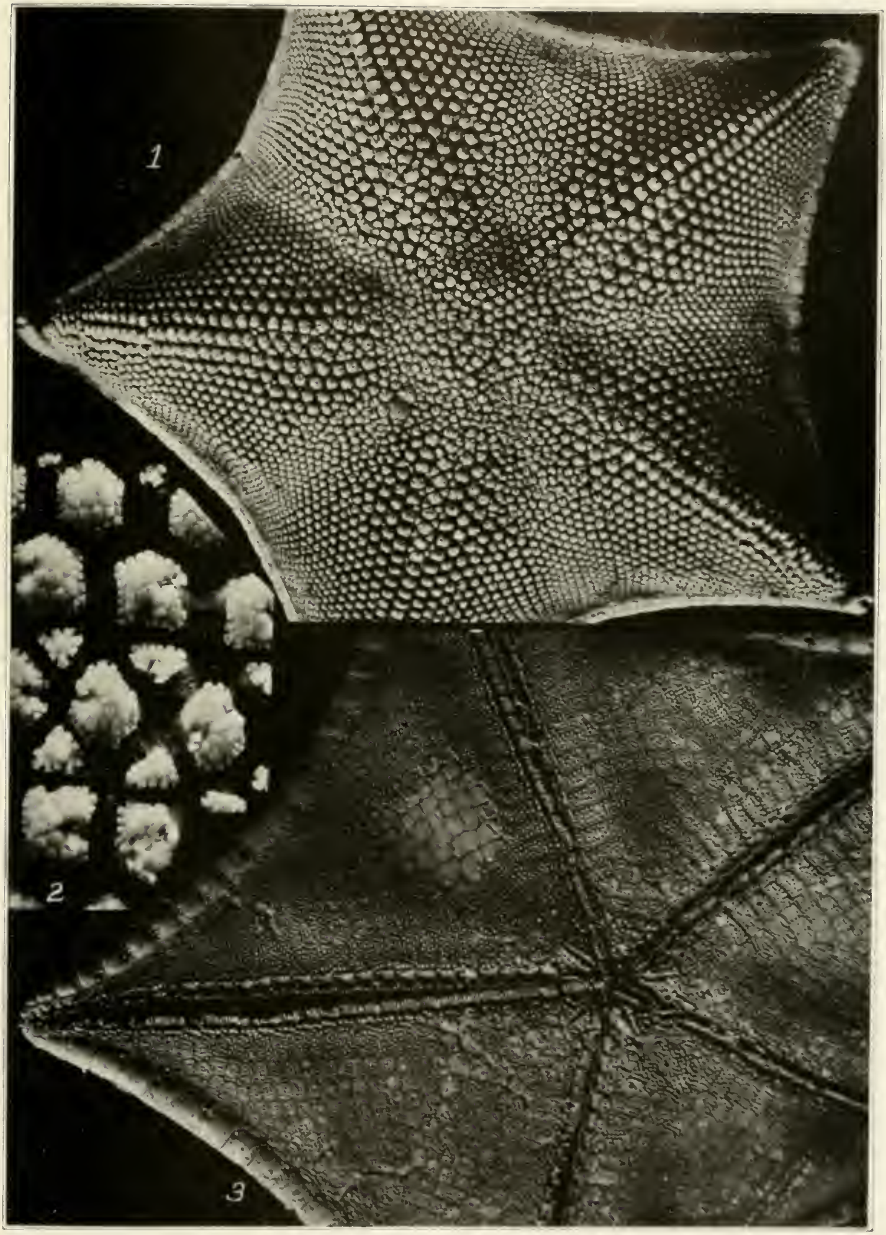
1–3. CERAMASTER JAPONICUS. 4. C. PATAGONICUS.

FOR EXPLANATION OF PLATE SEE PAGE 394.



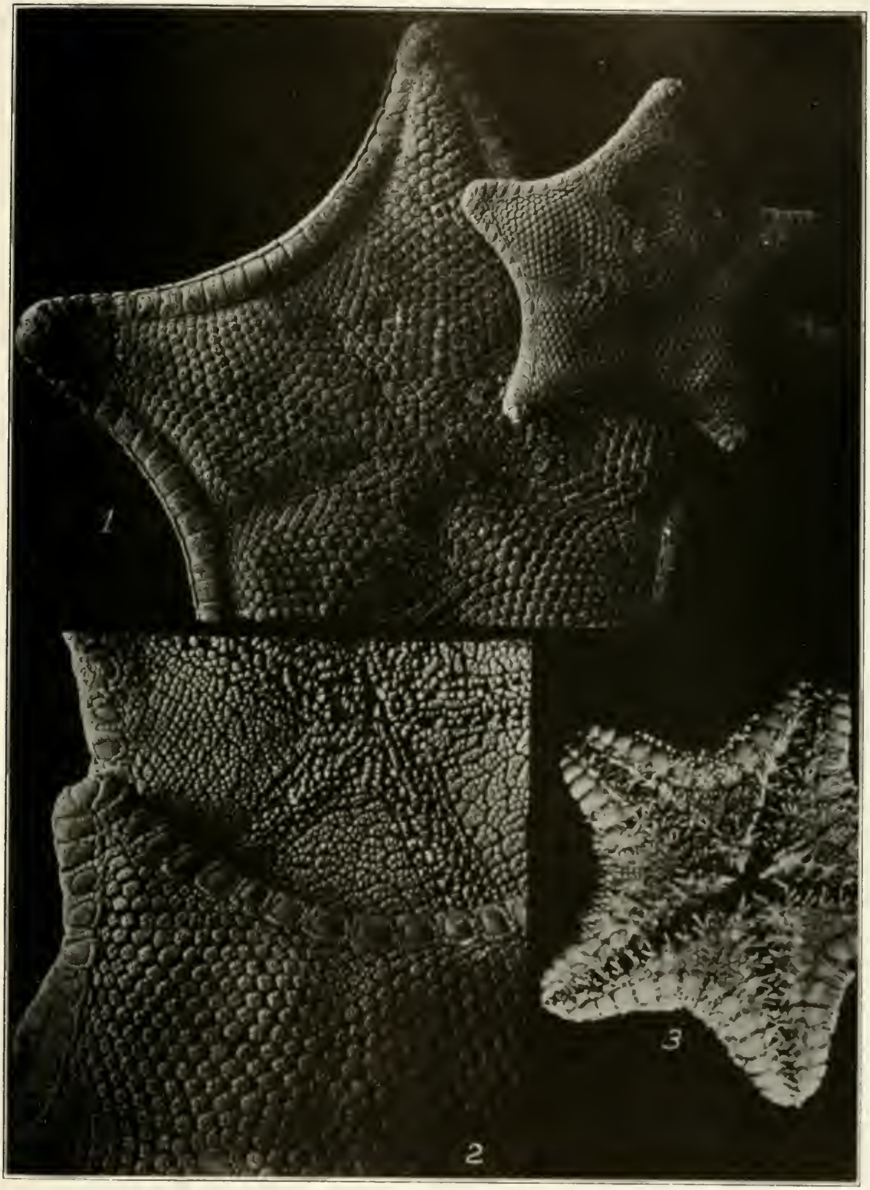
1, 2. CERAMASTER PATAGONICUS. 3, 4. C. CLARKI.

[illegible]



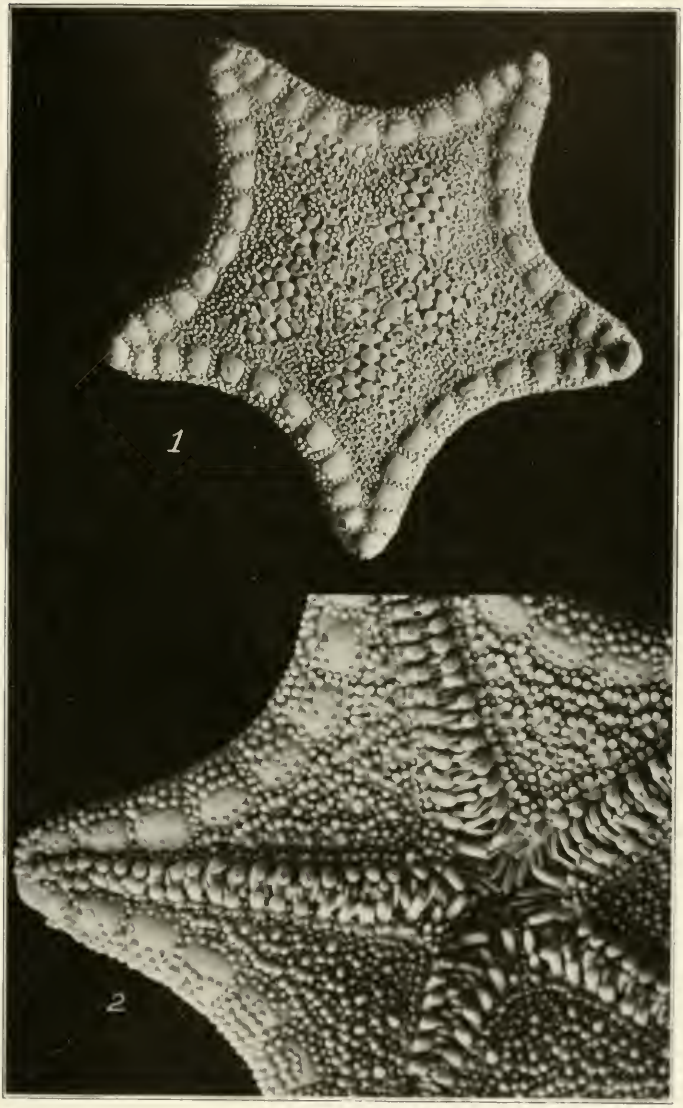
CERAMASTER LEPTOCERAMUS.

FOR EXPLANATION OF PLATE SEE PAGE 395.



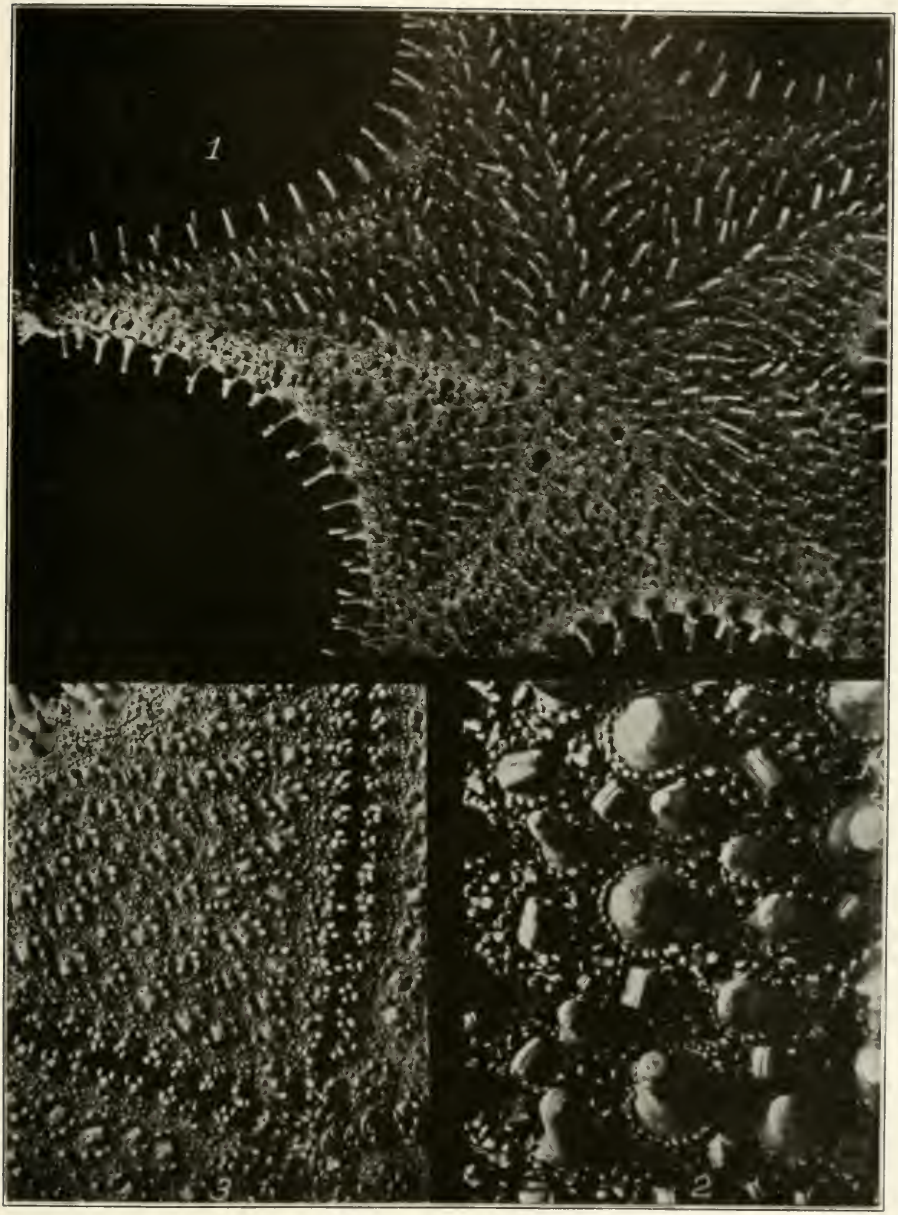
1, 2. CERAMASTER ARCTICUS. 3. PSEUDARCHASTER PARELII ALASCENSIS (VERY YOUNG).

FOR EXPLANATION OF PLATE SEE PAGE 395.



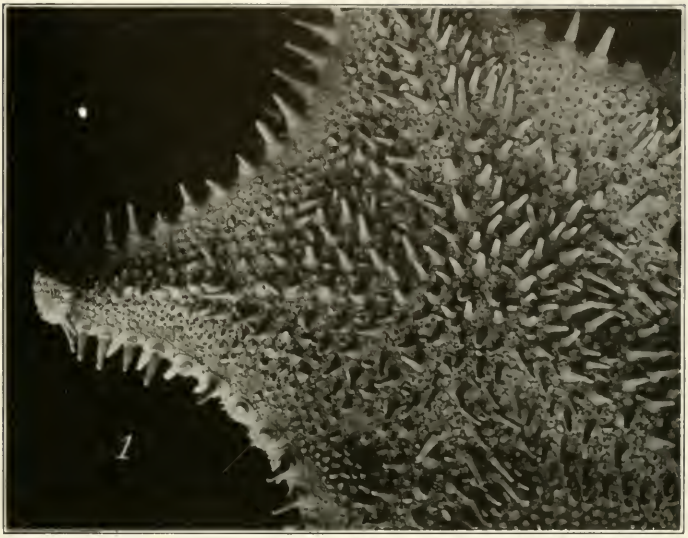
CLADASTER VALIDUS

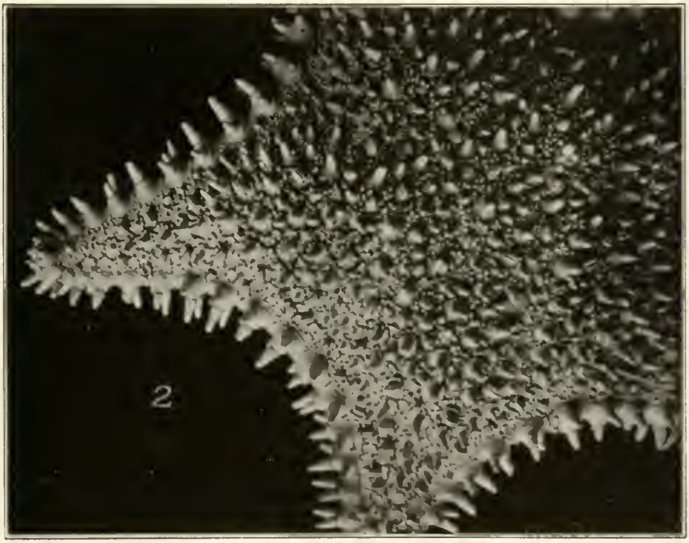
For explanation of plate see page 395.



HIPPASTERIA SPINOSA

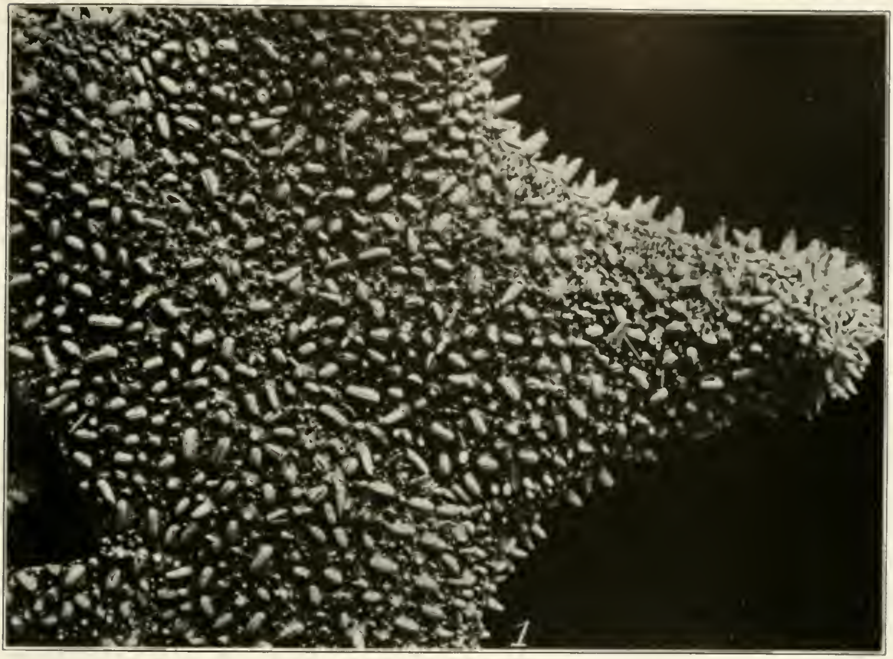
For explanation of plate see page [illegible].





1. HIPPASTERIA SPINOSA. 2. H. SPINOSA KURILENSIS.

For explanation of plate see page 3[illegible]



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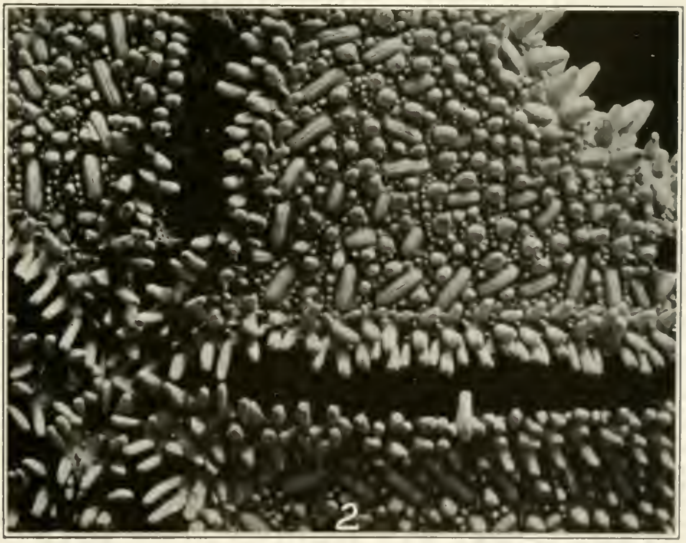
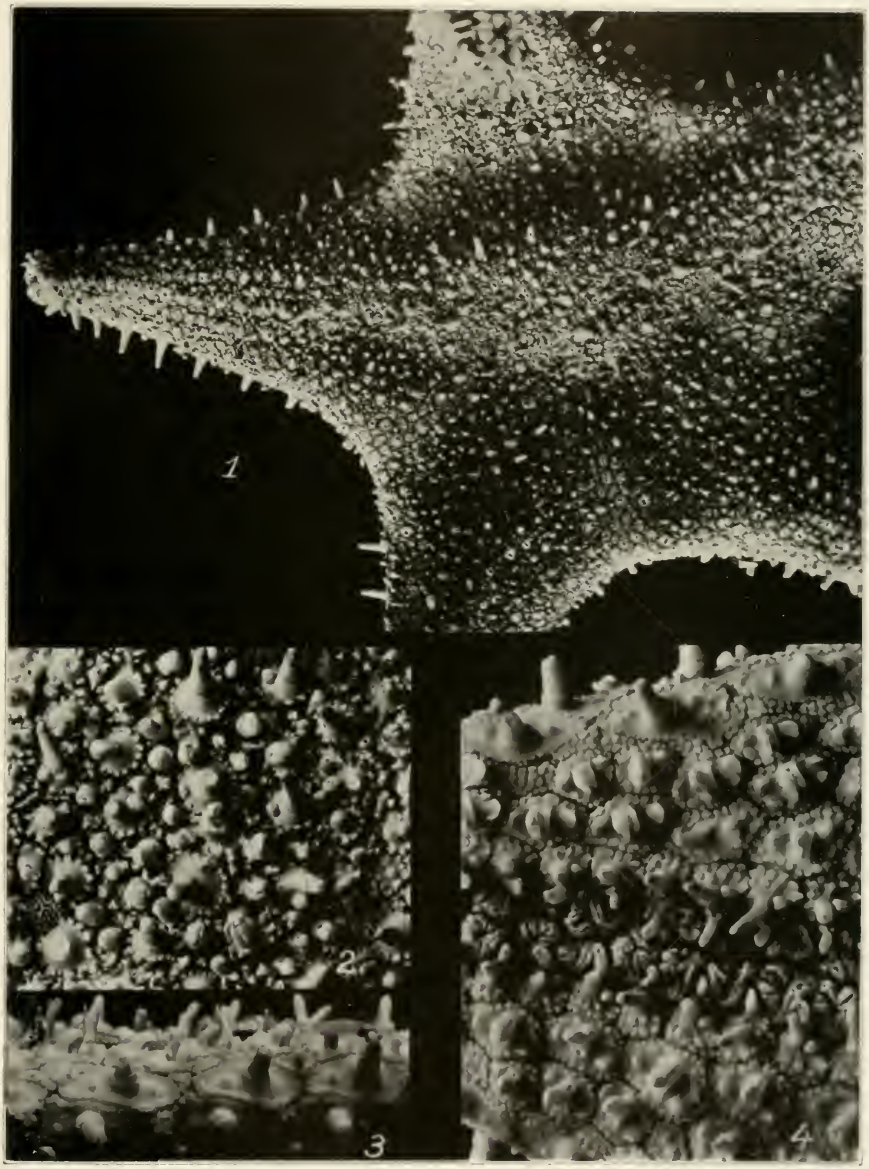


2

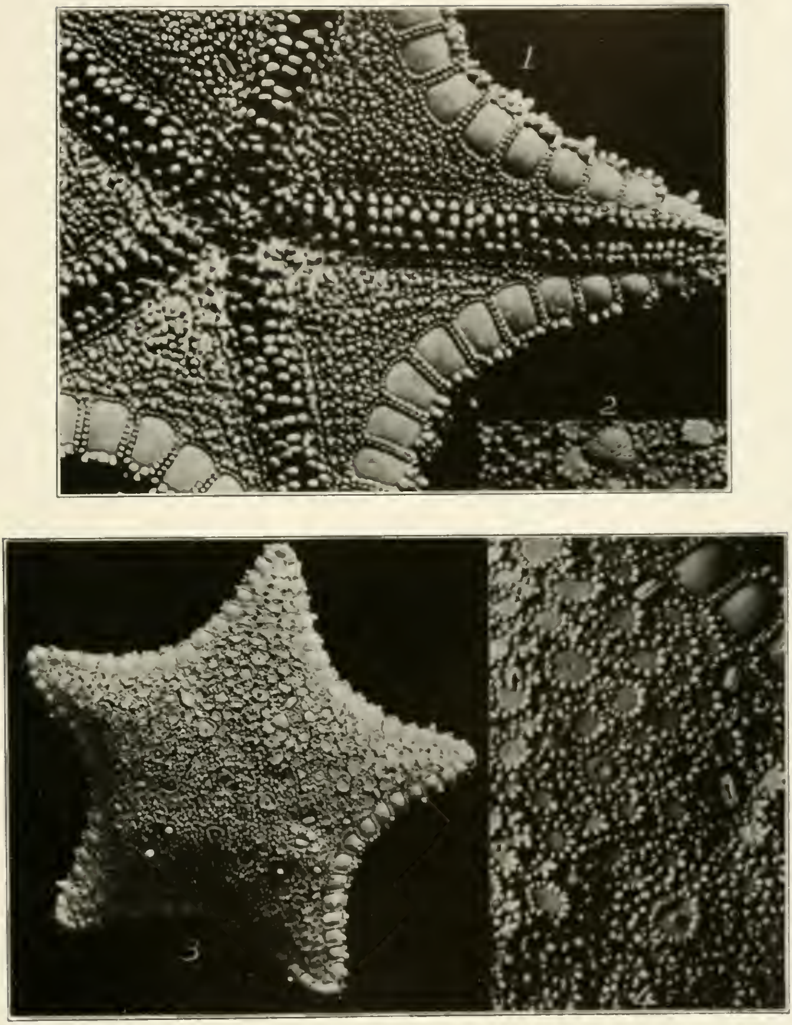
HIPPASTERIA HEATHI

FOR EXPLANATION OF PLATE SEE PAGE 195.



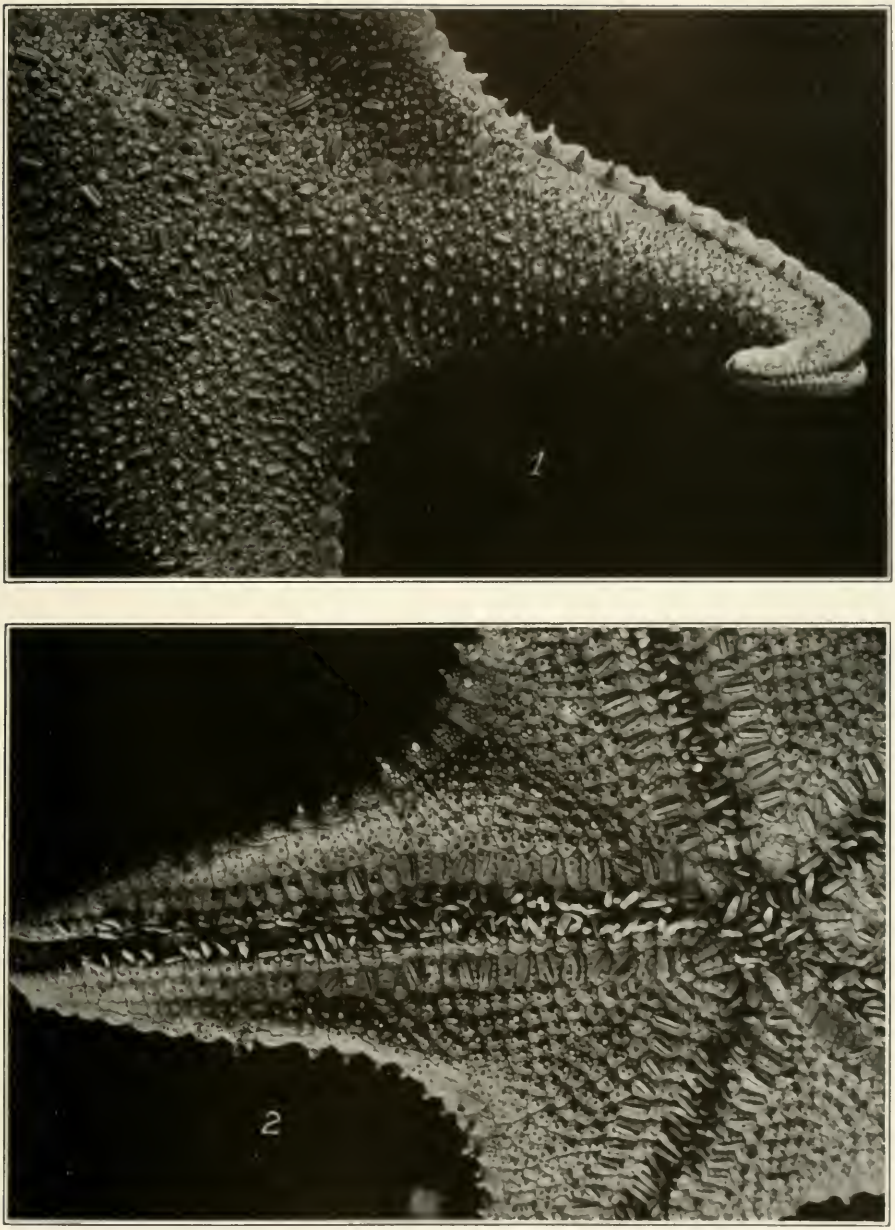
HIPPASTERIA CALIFORNICA

FOR EXPLANATION OF PLATE SEE PAGE 345.



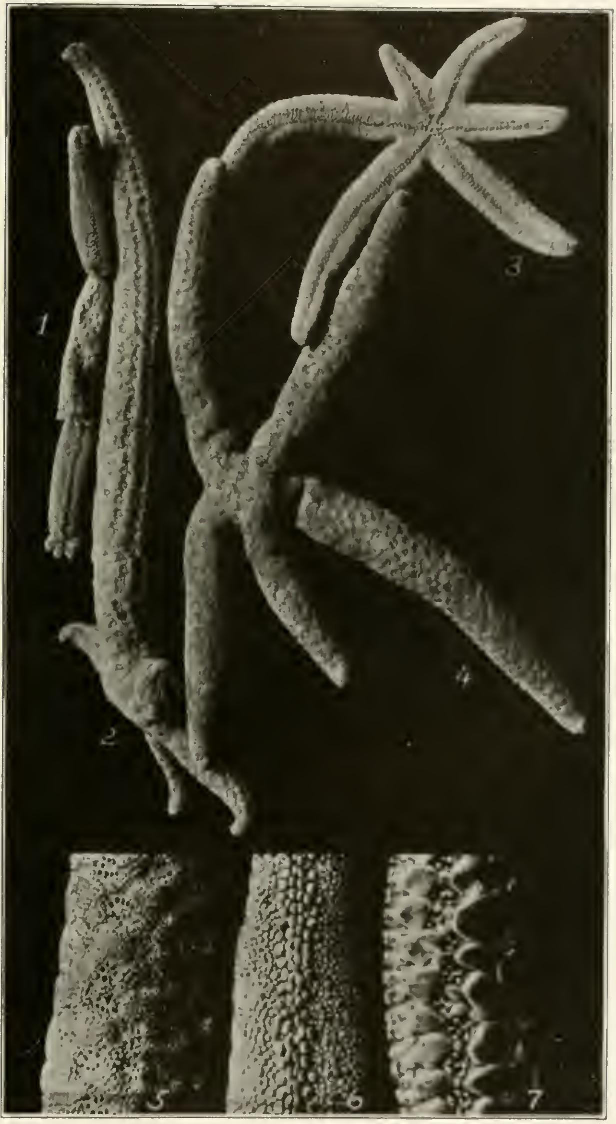
HIPPASTERIA LEIOPELTA

FOR EXPLANATION OF PLATE SEE PAGE 395



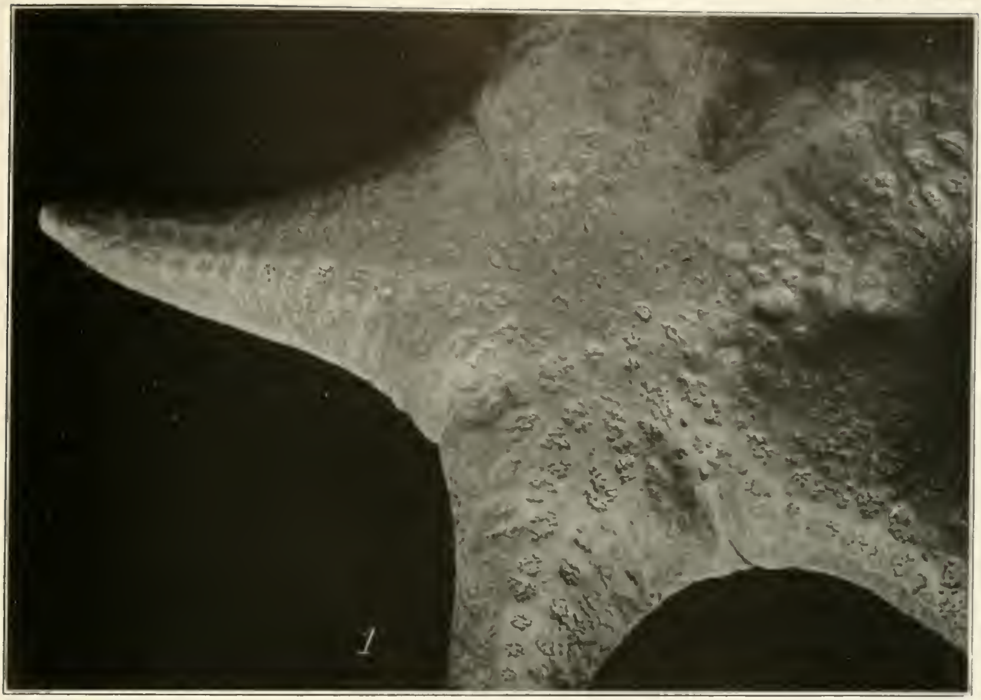
CRYPTOPELTASTER LEPIDONOTUS.

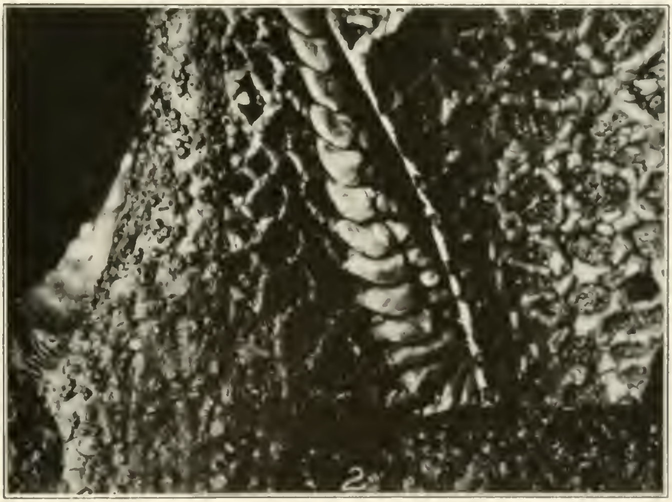
FOR EXPLANATION OF PLATE SEE PAGE 195.



LINCKIA COLUMBIÆ.

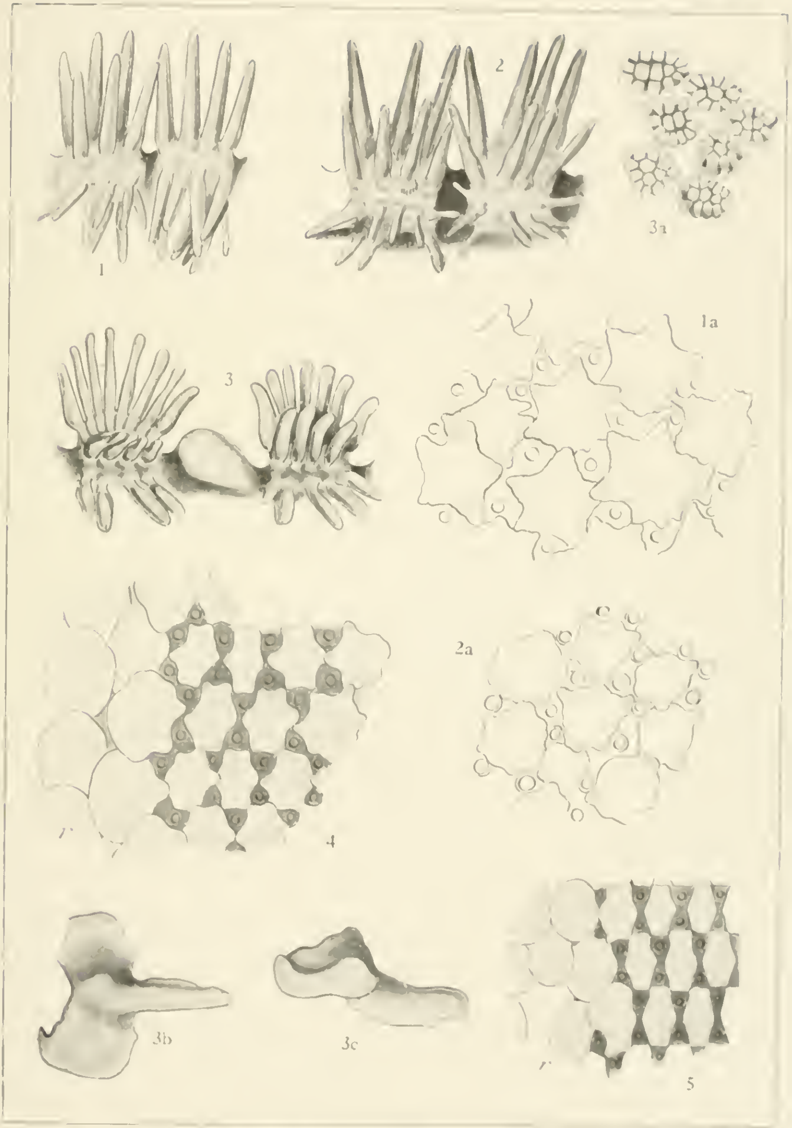
FOR EXPLANATION OF PLATE SEE PAGE 395.





DERMASTERIAS IMBRICATA

[illegible]


1
2
3a
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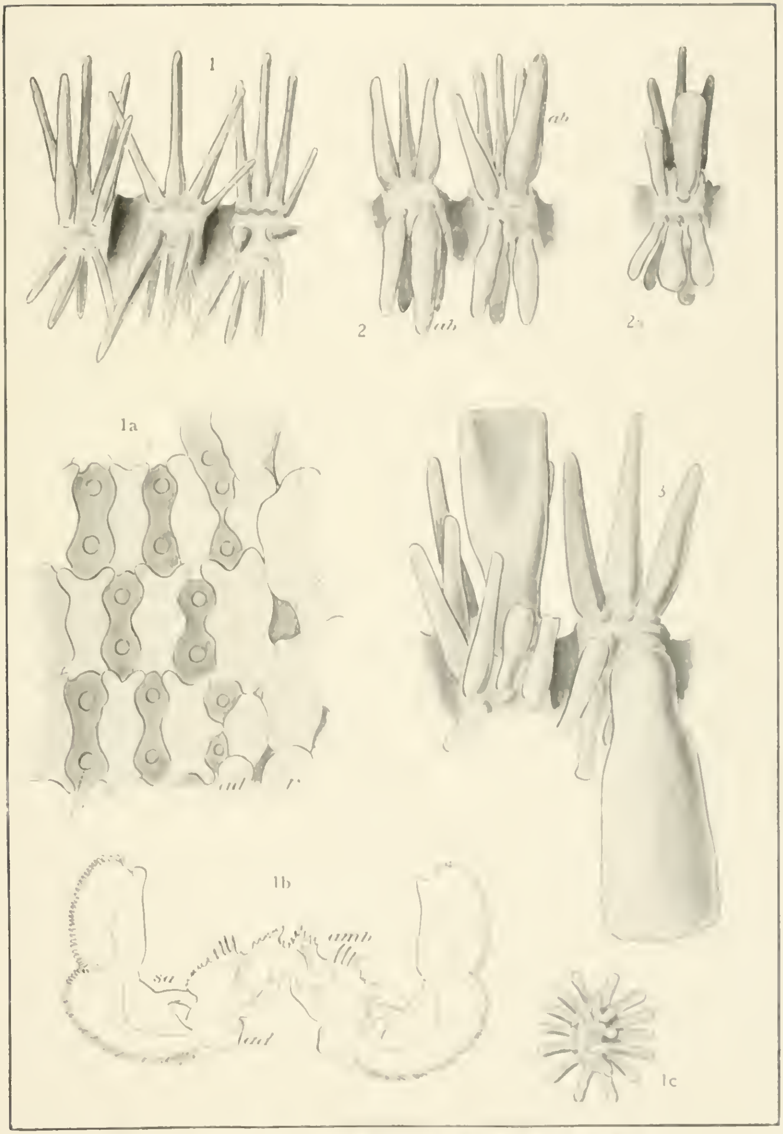
1a
2a
4
3b
3c
5

1. Leptychaster pacificus. 2. L. anomalus. 3. Psilaster pectinatus. 4. Astropecten armatus.
5. A. californicus.

[illegible]


1
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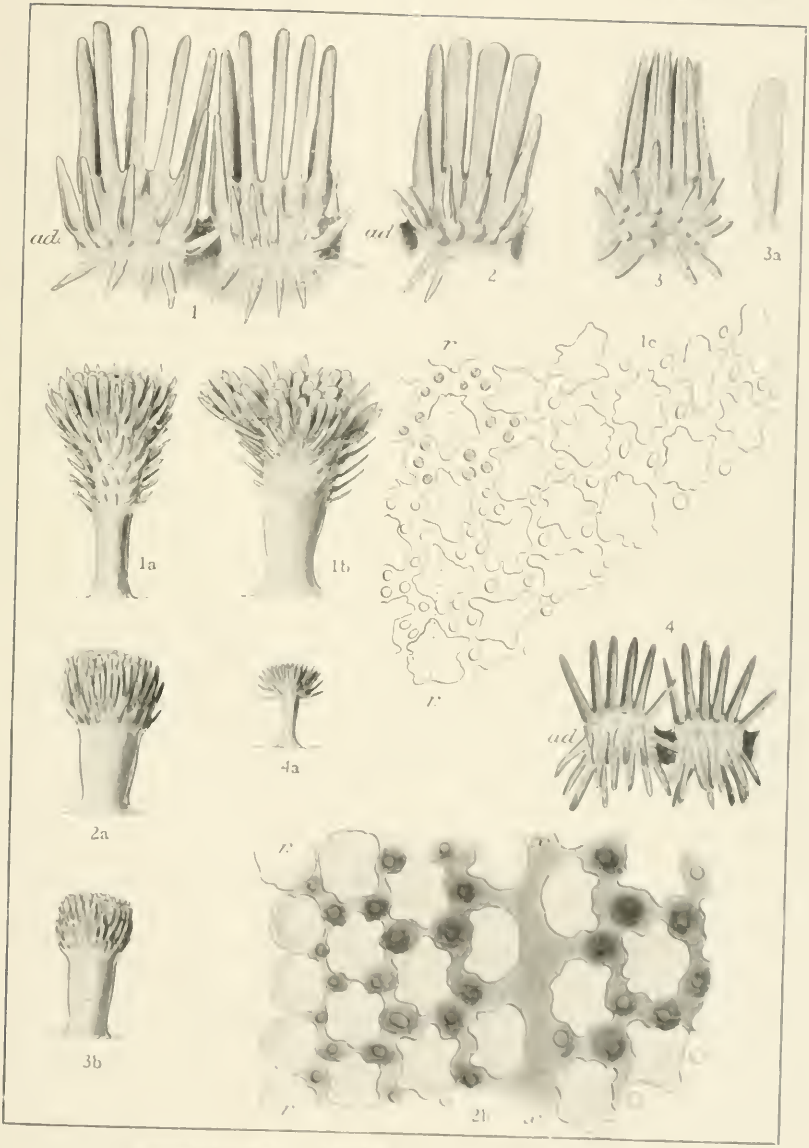
ab
2a
1a
3
ad
r
1b
amb
sa
ad
1c

1. A[illegible]THO[illegible]CETEN [illegible]NAT[illegible] 2. A. [illegible] 3. A. [illegible]

[illegible]


ad
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ad
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3
3a
r
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4
ad
2a
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3b
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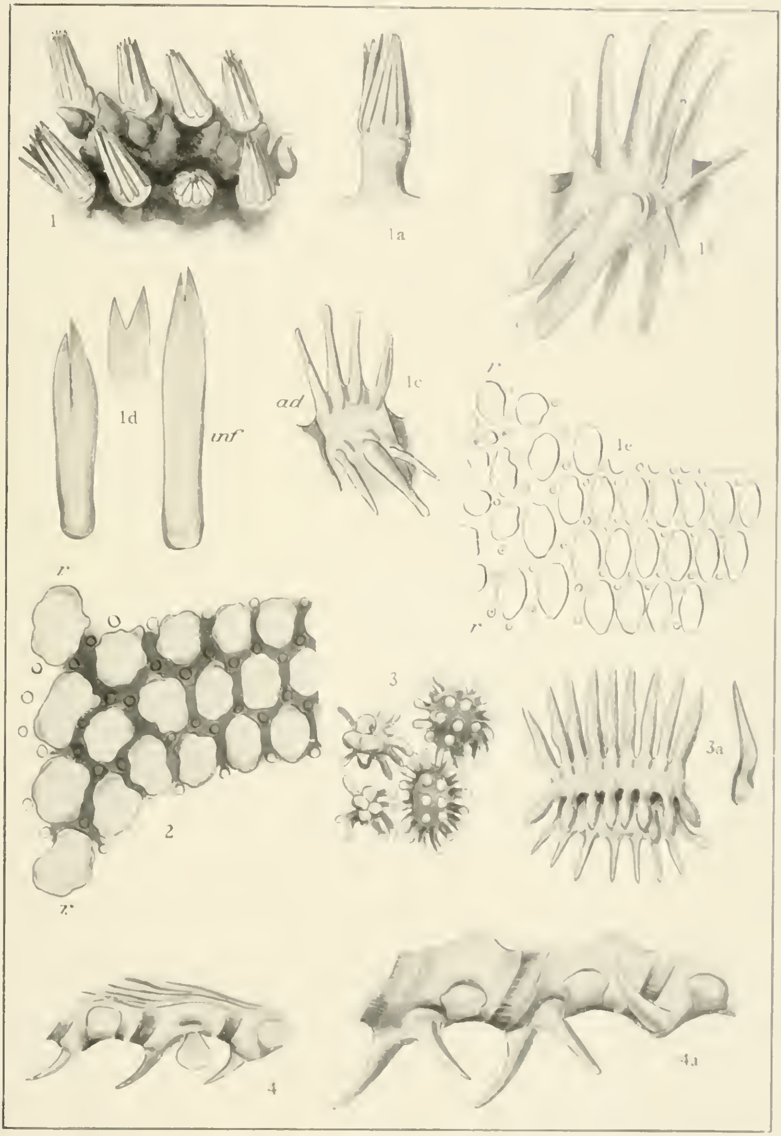
2b
x

1. D[illegible]tes eximia. 2. D. [illegible] 3. D. [illegible] 4. D. [illegible]

F[illegible]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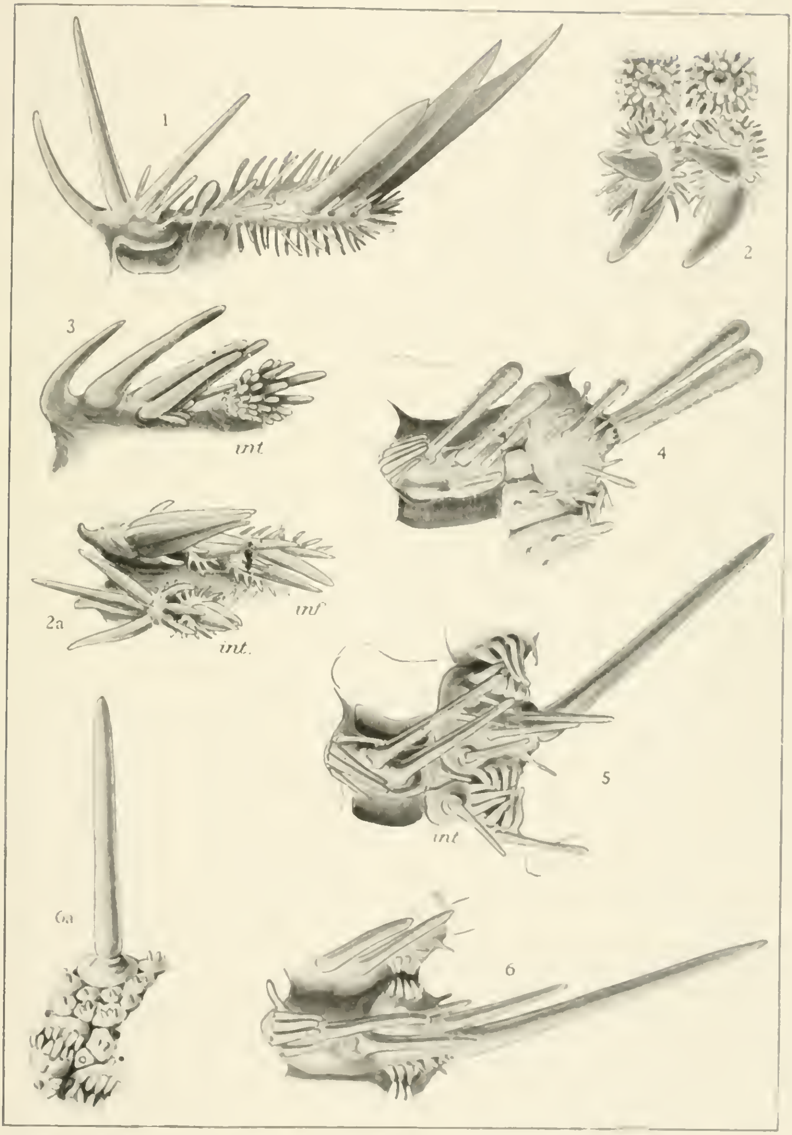
1. Thri[illegible]acanth[illegible] fa[illegible]ata. 2. D[illegible]. 3. D[illegible]. 4. E[illegible] tene[illegible]ata.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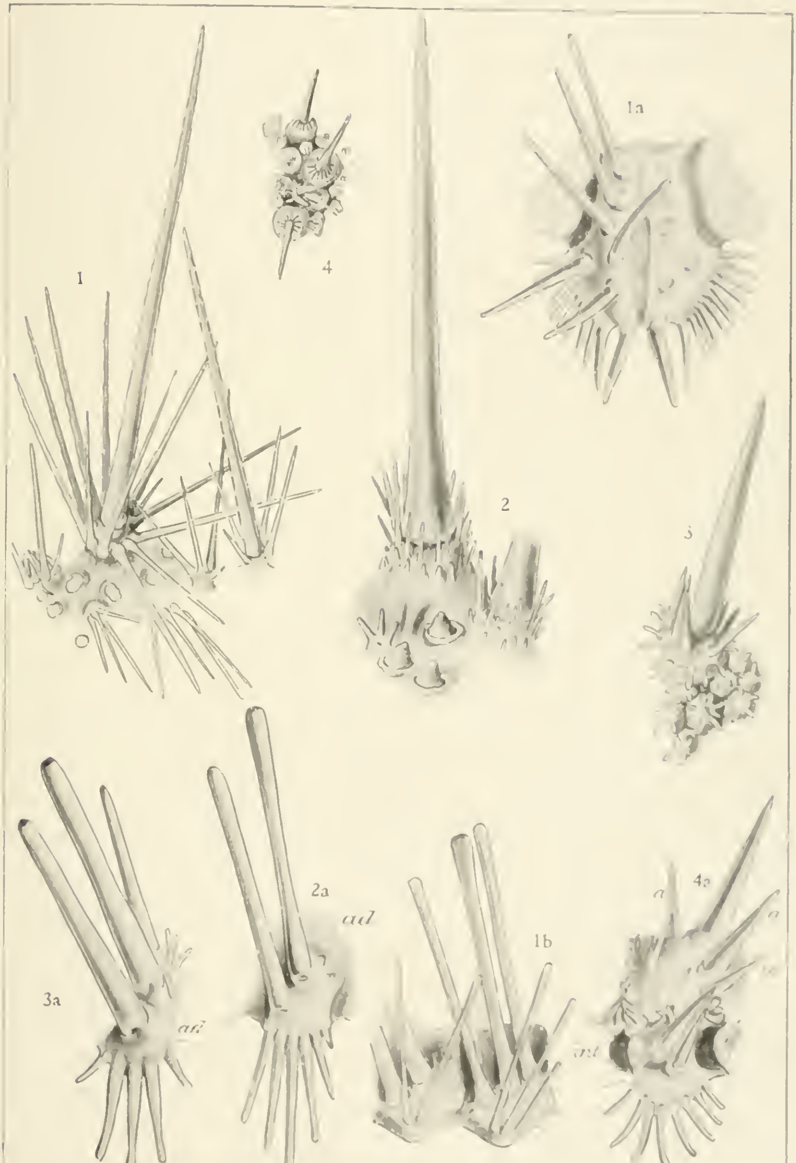
5
int
6a
6

1. L[illegible]a asthen[illegible]ma. 2. L. l[illegible]. 3. L. f[illegible]lata. 4. B[illegible]. 5. B. a[illegible]anth[illegible].
6. B. [illegible]ta[illegible].

[illegible]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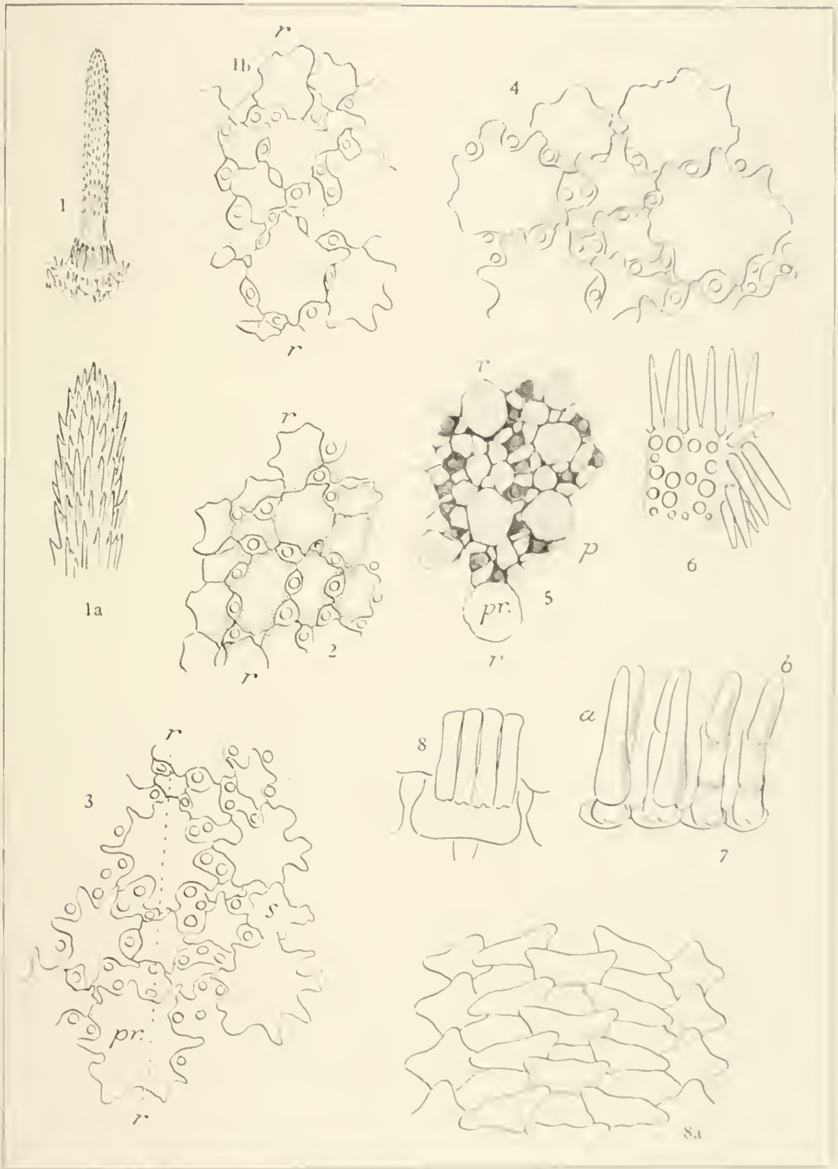
1. NEARCHASTER A[illegible]. 2. N. [illegible]. 3. L[illegible]. 4. P[illegible].

[illegible]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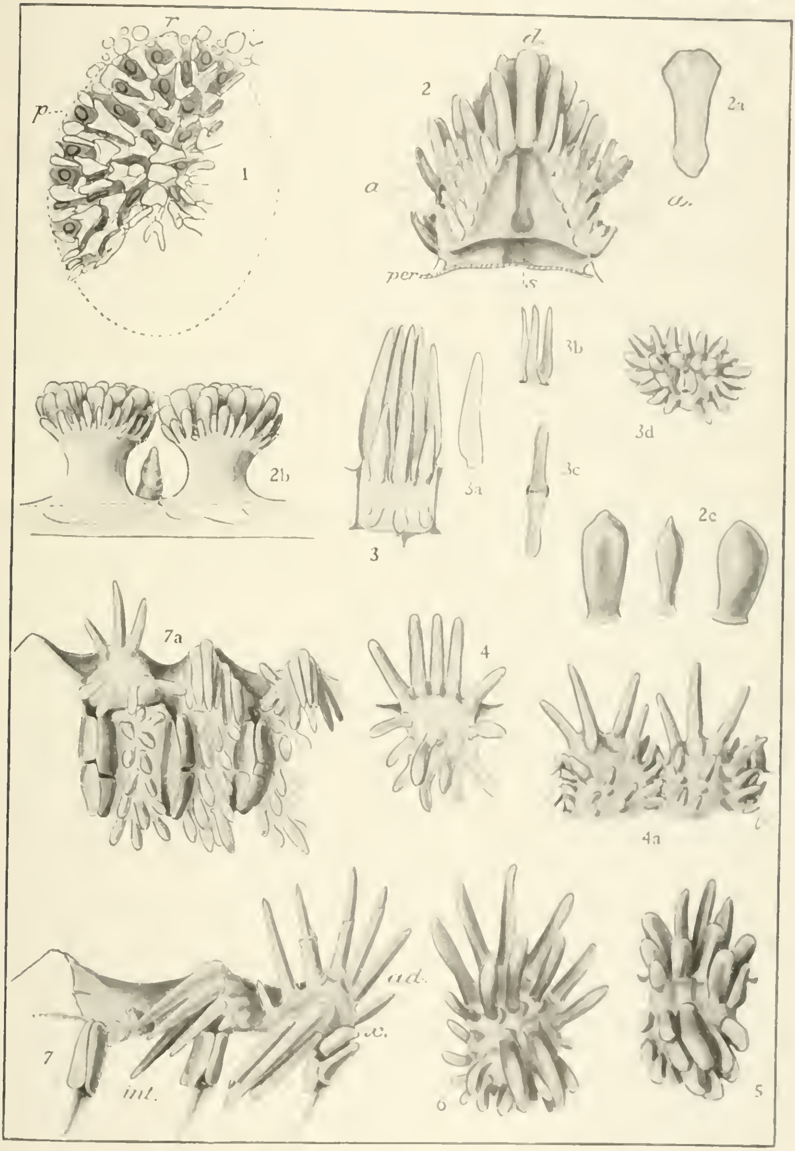
1. Benthopecten flaviger. 2. B. acanthonotus. 3. Nearchaster aciculosus. 4. N. variabilis. 5. Lophaster dawsoni. 6. Odontaster crassus. 7. Dermasterias imbricata. 8. Asterina miniata.

[illegible]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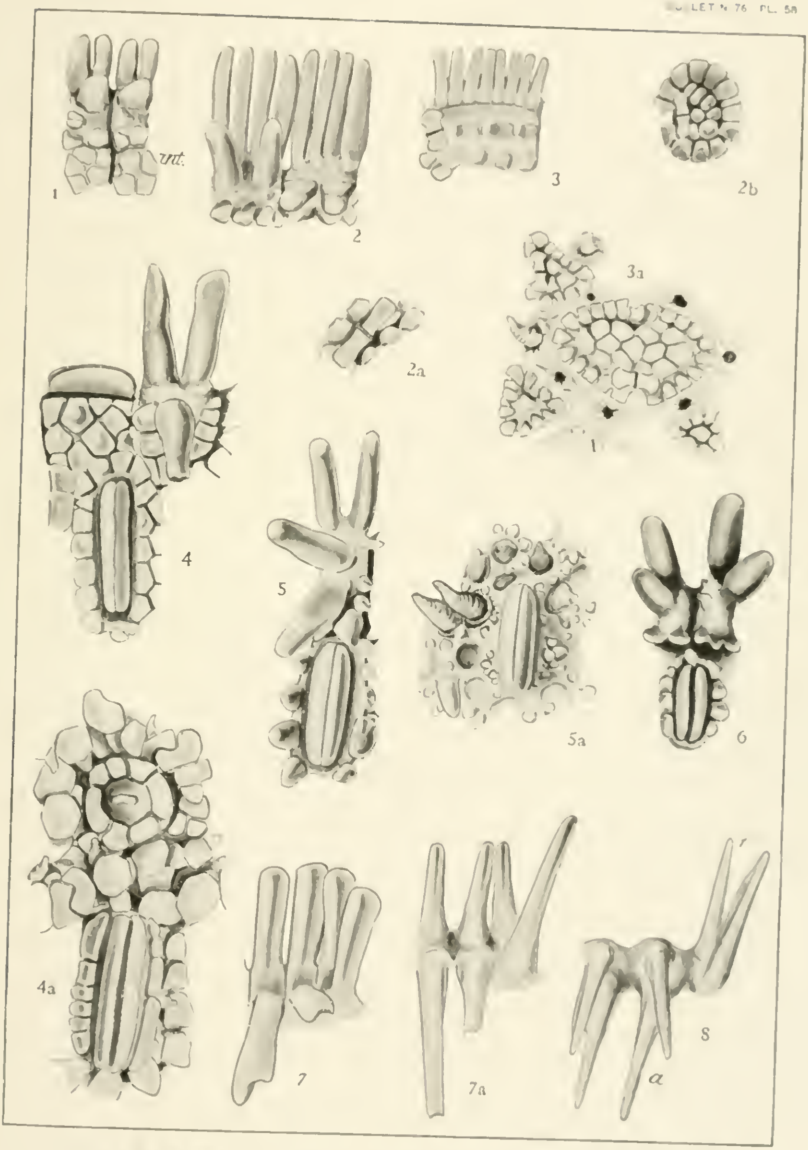
5

1. PECTINASTER AGASSIZI EVOPLUS. 2. GEPHYREASTER SWIFTI. 3. MEDIASTER AEQUALIS. 4. PSEUDARCHASTER PUSILLUS. 5. PS. PARELII. 6. PS. ALASCENSIS. 7. PS. DISSONUS.

[illegible]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7a
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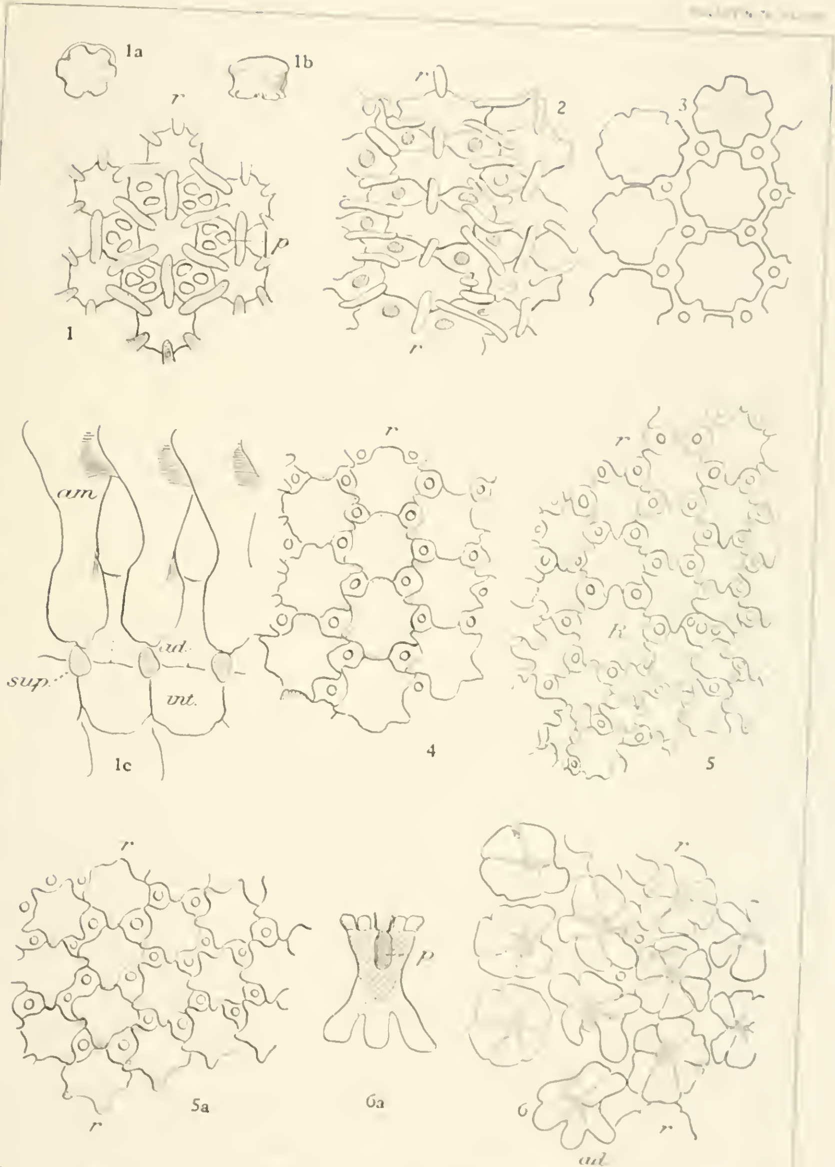
a

1. Ceramaster arcticus. 2. C. [illegible] 3. C. leptoceramus. 4. Cryptopeltaster lepidonotus. 5. Hippasteria heathi. 6. H. [illegible]. 7. Poraniopsis inflata. 8. P. inflata [illegible]

[illegible]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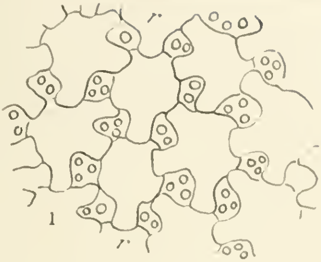
1. Mediaster æqualis. 2. M. tenellus. 3. Ceramaster japonicus. 4. Pseudarchaster pusillus.
5. Gephyreaster swifti. 6. Ceramaster clarki.

For explanation of plate see page [illegible]



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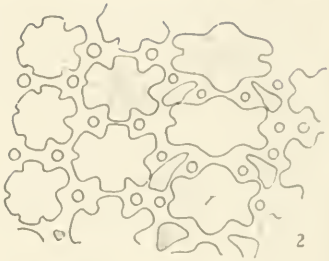

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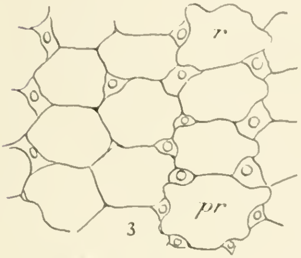

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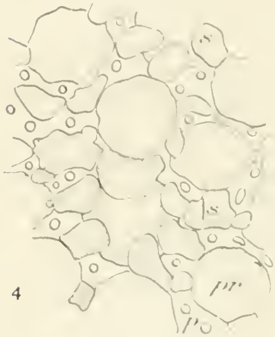

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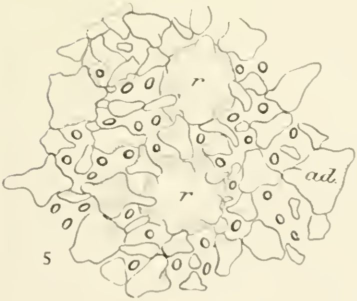

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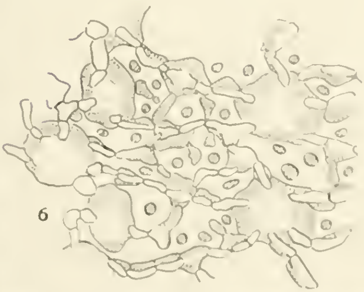

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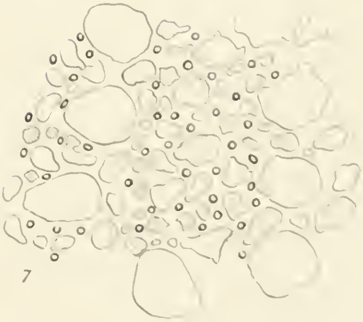
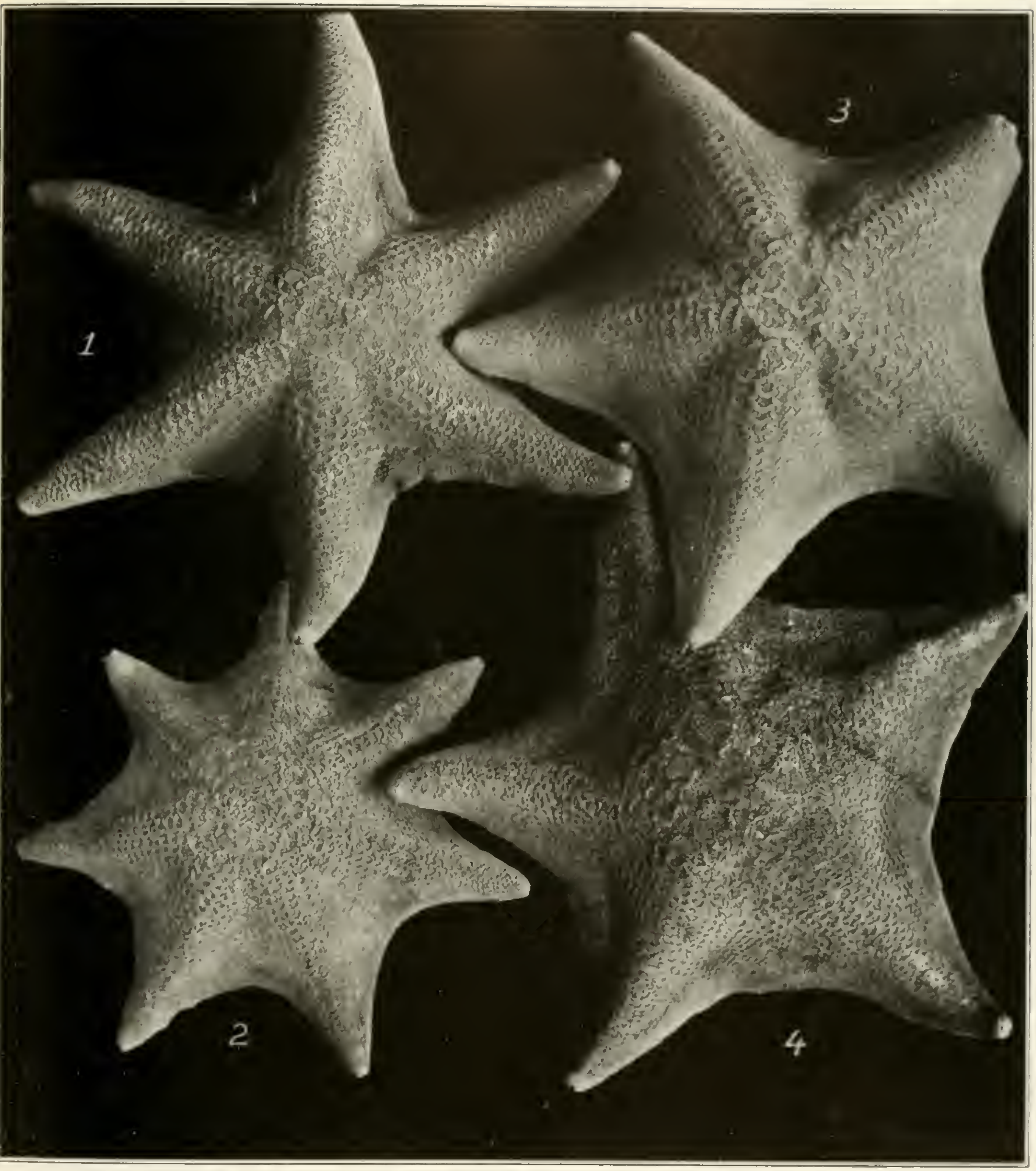


7

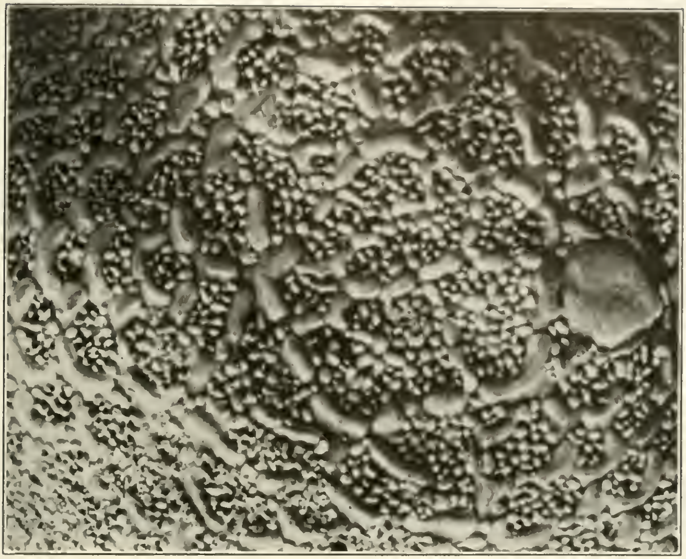
1. Ceramaster arcticus. 2. C. leptoceramus. 3. C. patagonicus. 4. Hippasteria spinosa. 5. H. californica.
6. H. heathi. 7. Cryptopeltaster lepidonotus.

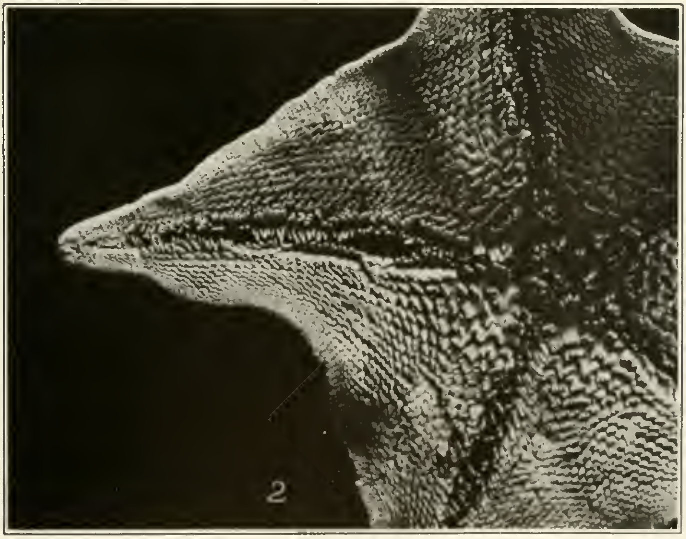
For explanation of plate see page [illegible]



Asterina miniata

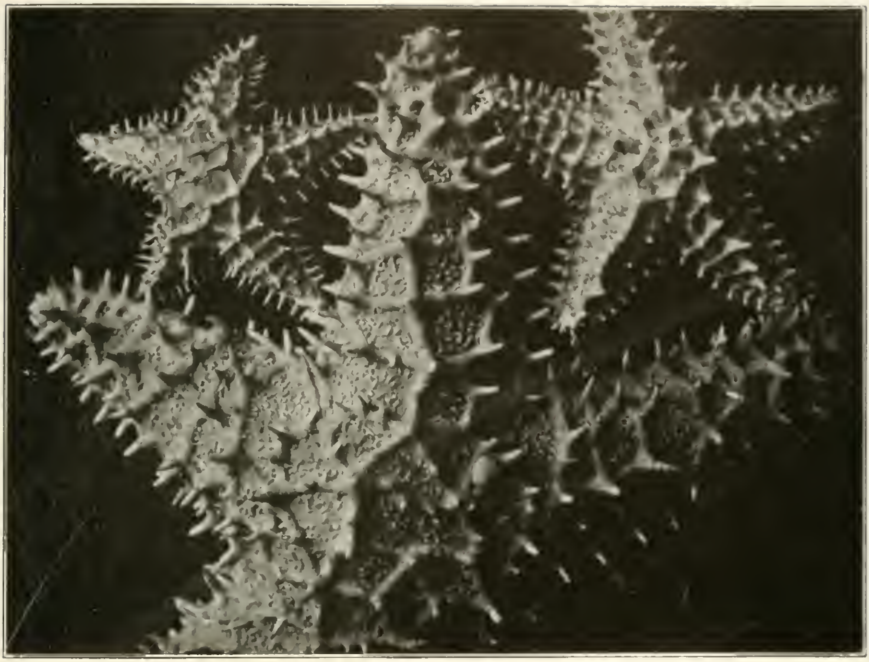
For explanation of plate see page 399.

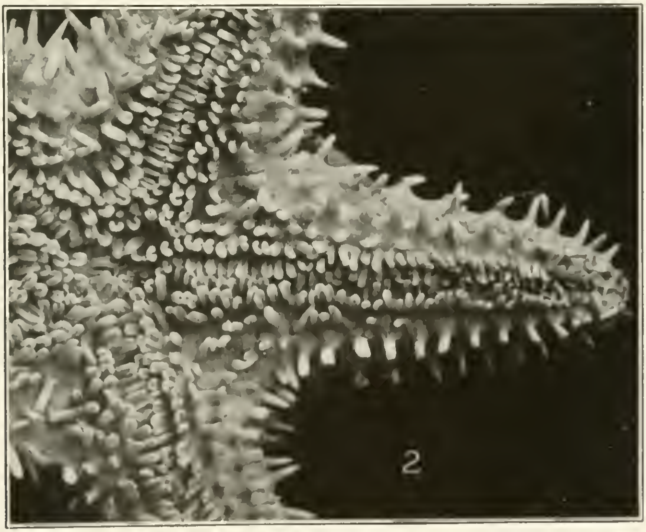




ASTERINA MINIATA.

FOR EXPLANATION OF PLATE SEE PAGE 399.

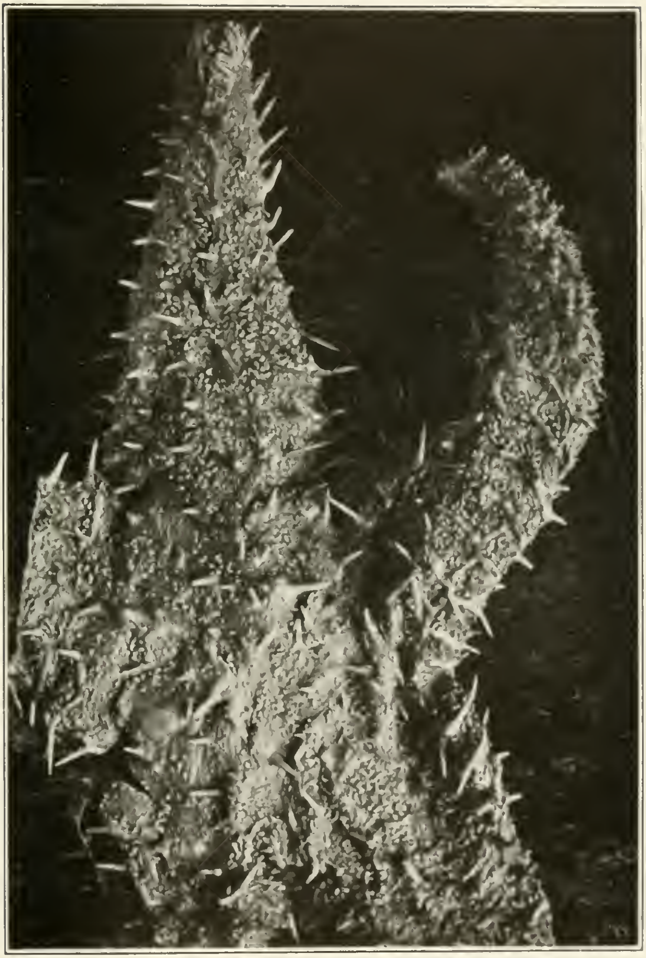




2

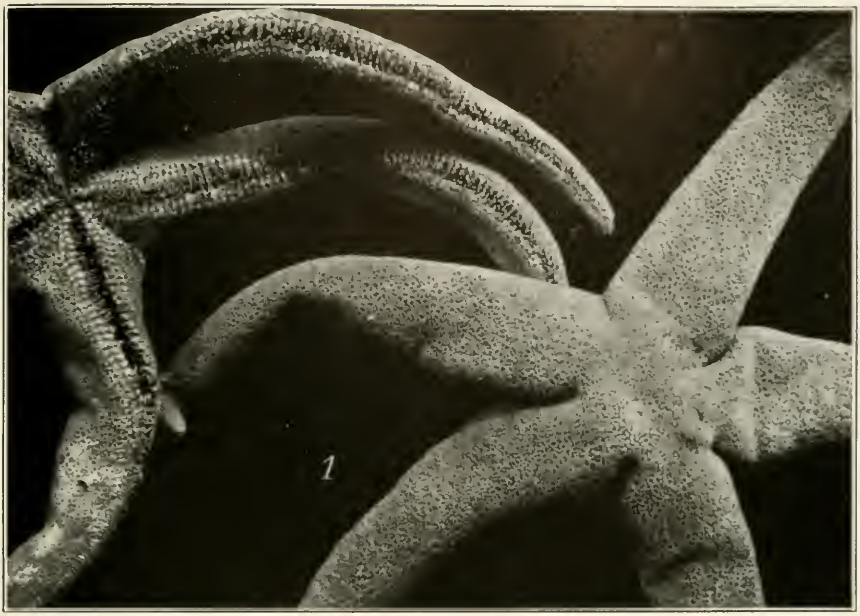
PORANIOPSIS INFLATA.

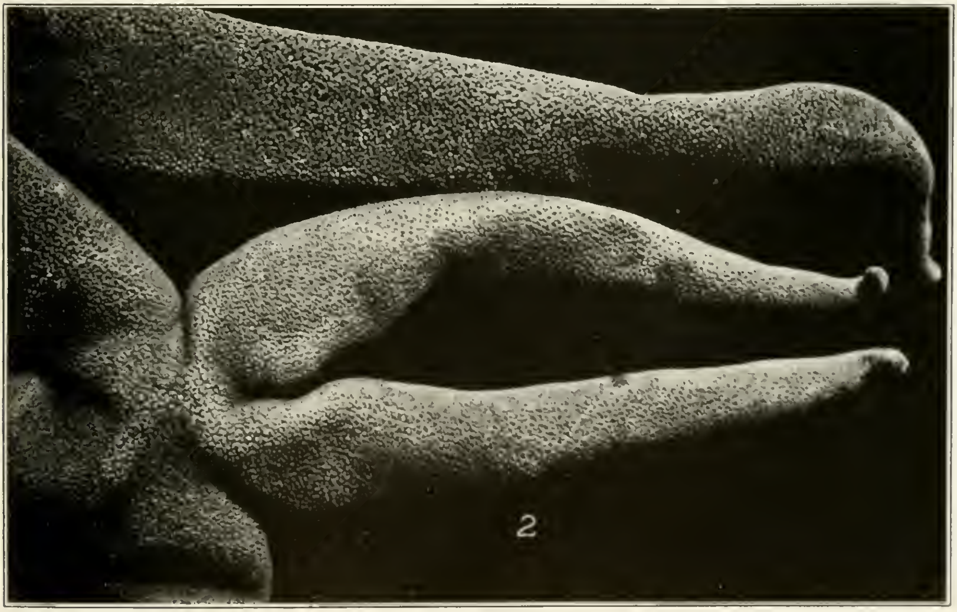
FOR EXPLANATION OF PLATE SEE PAGE 399



PORANIOPSIS INFLATA FLEXILIS.

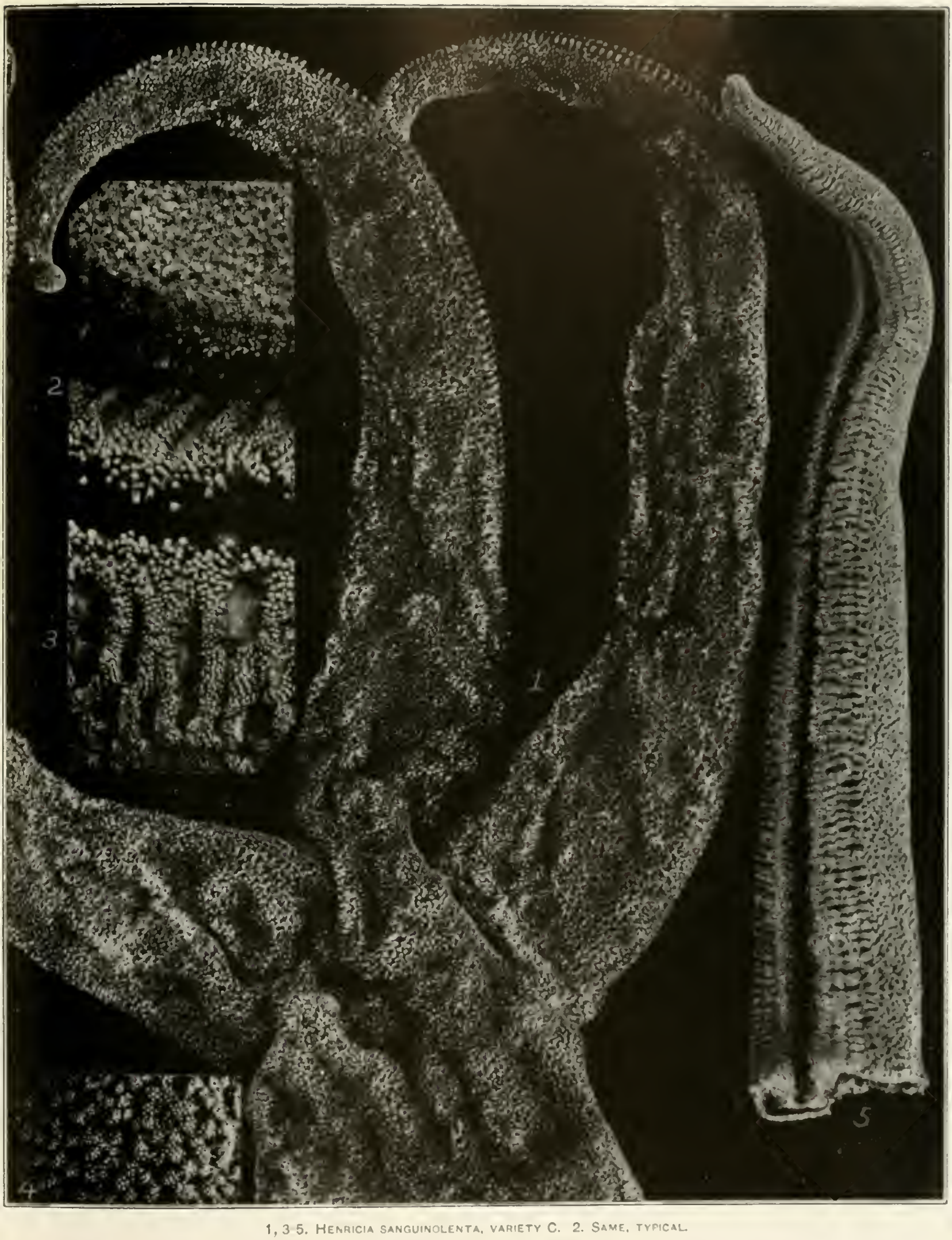
FOR EXPLANATION OF PLATE SEE PAGE 399.





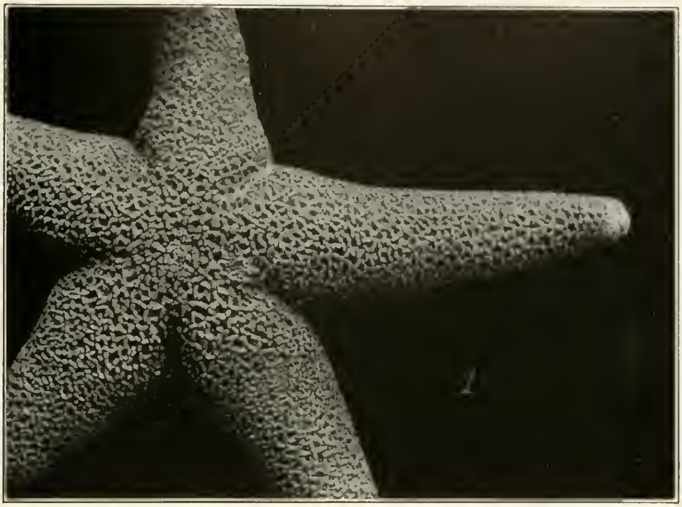
1. Henricia sanguinolenta. 2. Same, variety C.

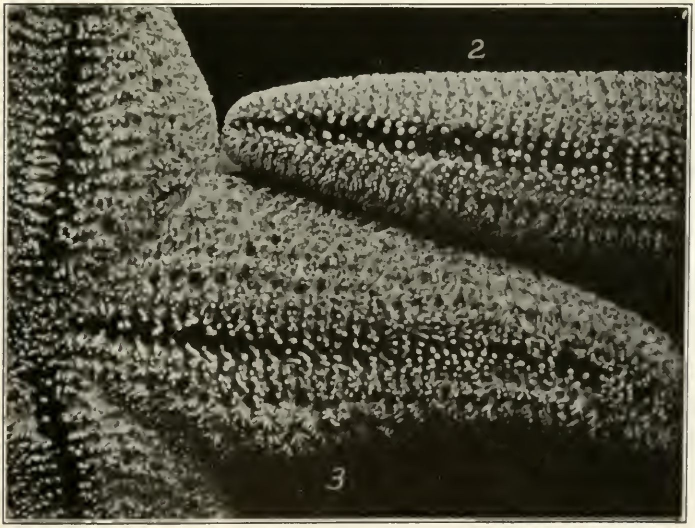
For explanation of plate see page 399.



1, 3-5. HENRICIA SANGUINOLENTA, VARIETY C. 2. SAME, TYPICAL.

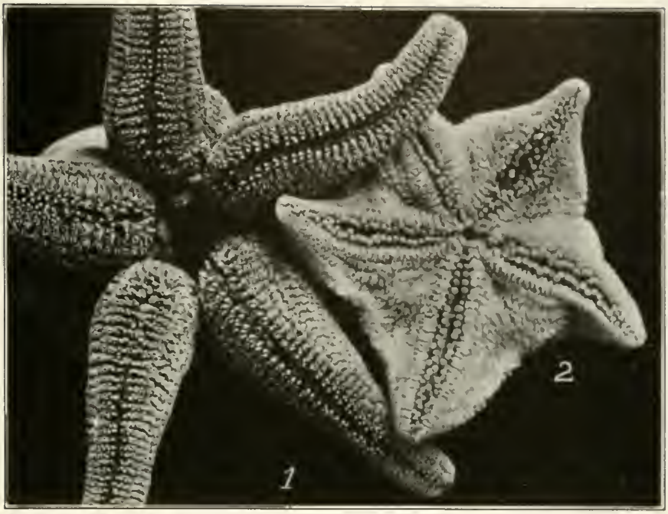
FOR EXPLANATION OF PLATE SEE PAGE [illegible]99.

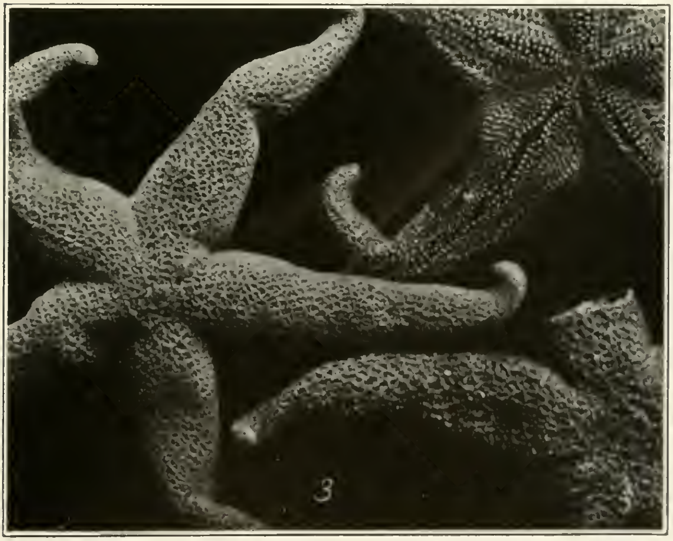




HENRICIA SANGUINOLENTA ESCHRICHTI.

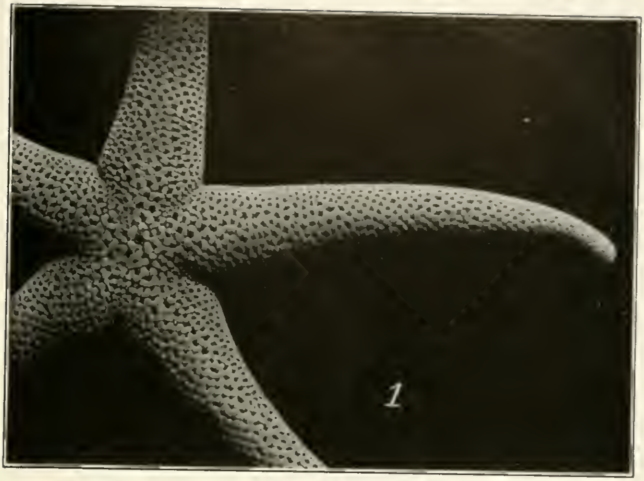
FOR EXPLANATION OF PLATE SEE PAGE 400.

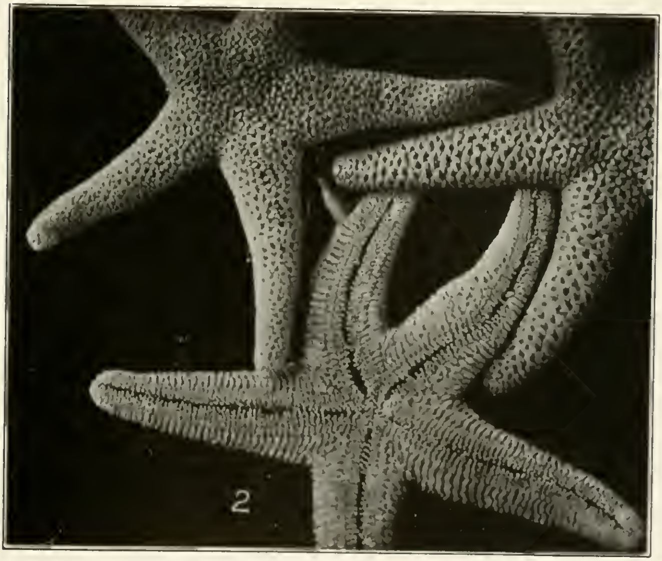




1, 2. Henricia sanguinolenta eschrichtii. 3. H. sanguinolenta, variety E.

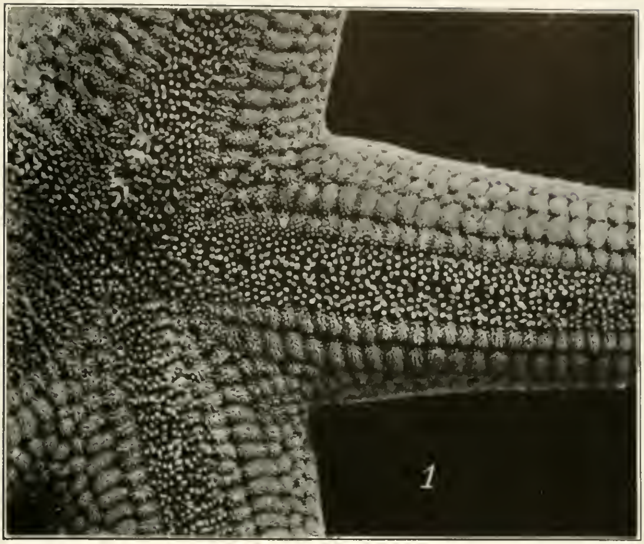
For explanation of plate see page 400.

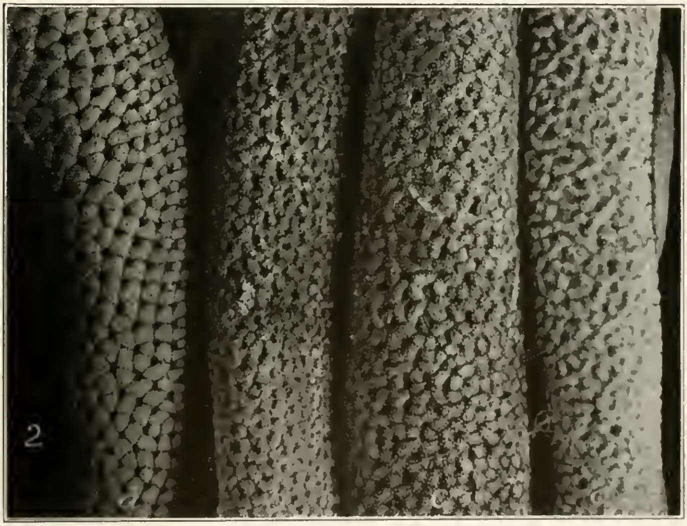




1. Henricia leviuscula, variety A 2. Same, variety F.

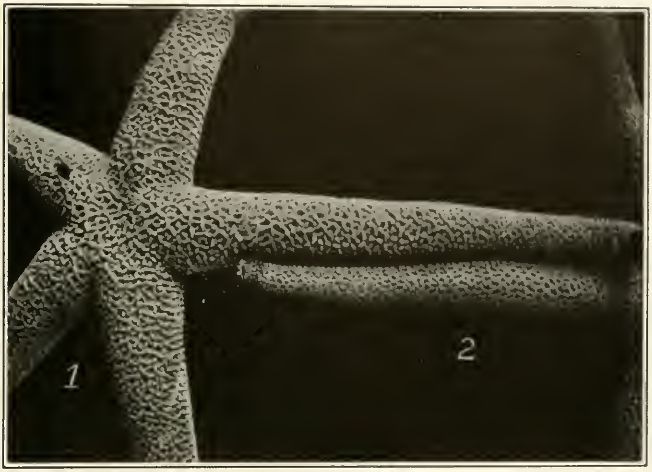
For explanation of plate see page 400

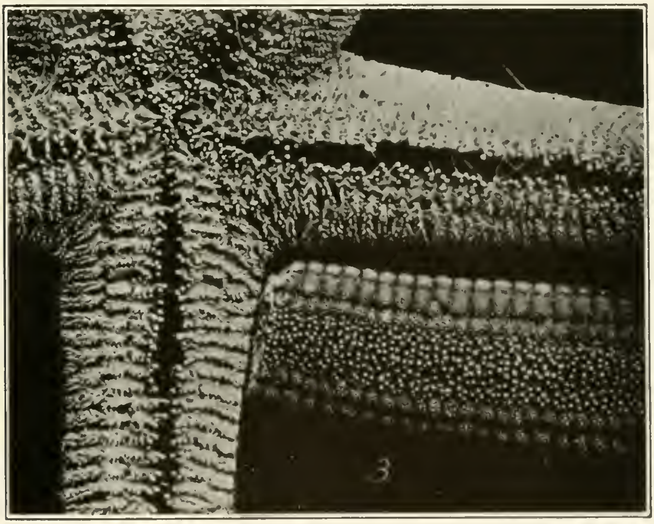




1, 2*a*. Henricia leviuscula. 2*b*, *c*. Same, variety B; 2*d* H. leviuscula annectens.

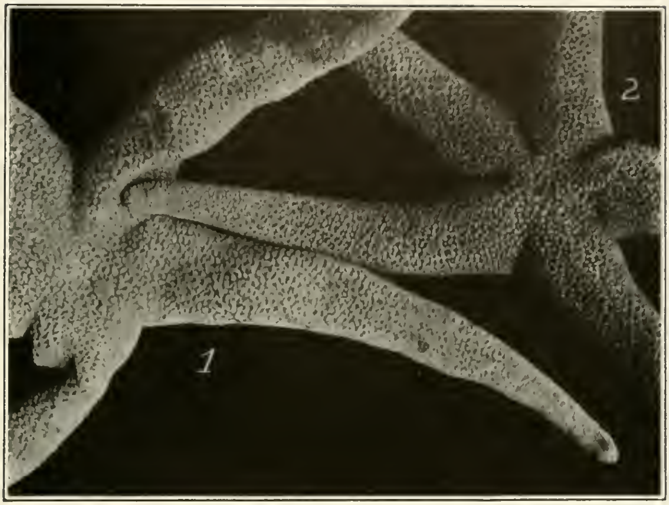
For explanation of plate see page 400.

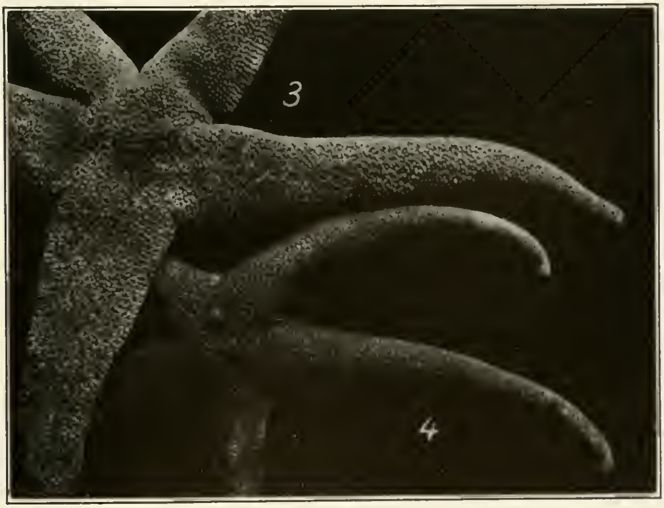




1, 3 (UPPER). HENRICIA LEVIUSCULA ANNECTENS. 2, 3 (LOWER). H. LEVIUSCULA

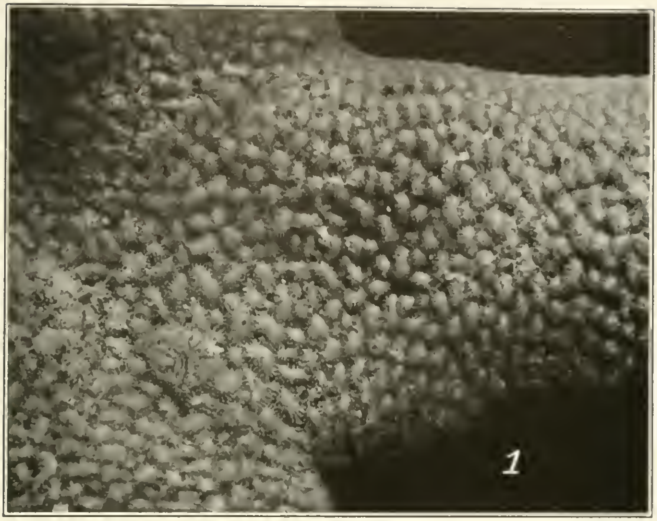
FOR EXPLANATION OF PLATE SEE PAGE 400.





HENRICIA LEVIUSCULA MULTISPINA.

FOR EXPLANATION OF PLATE SEE PAGE 400.



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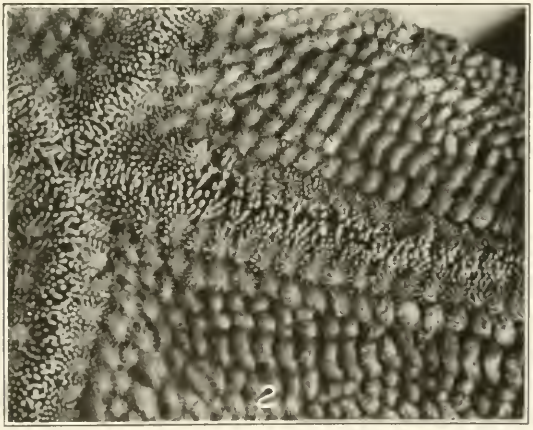
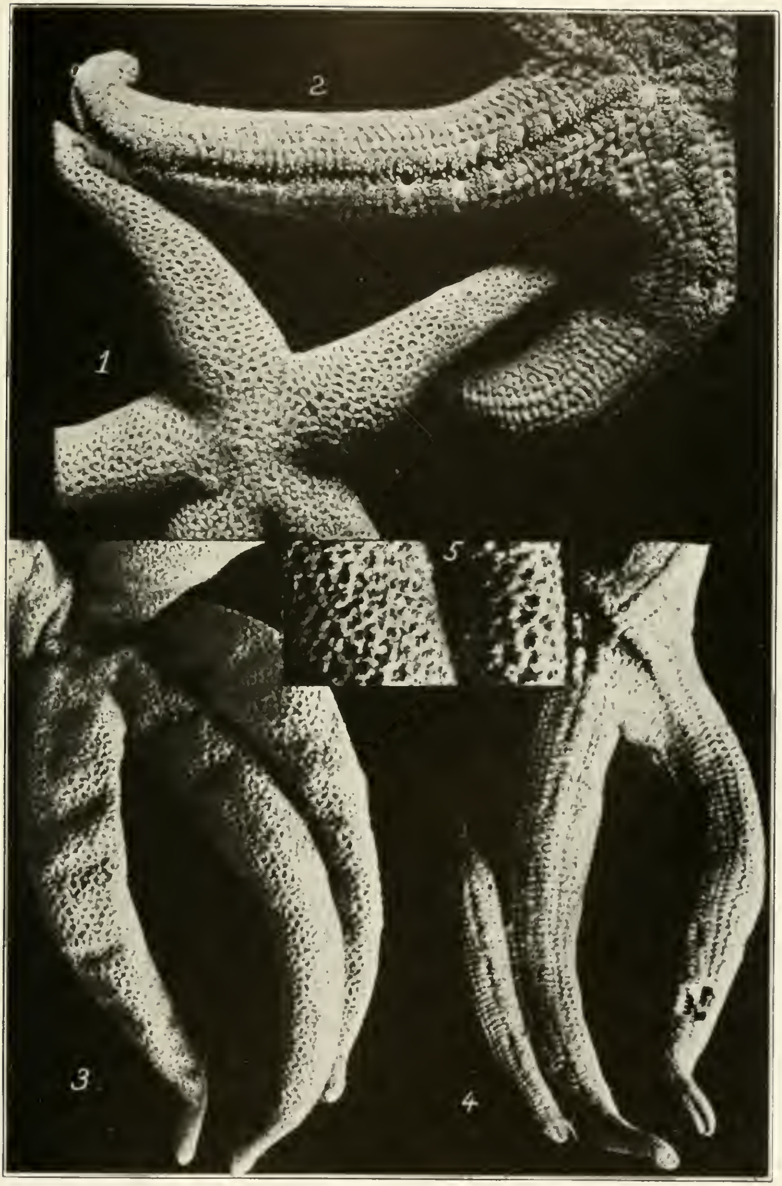


2

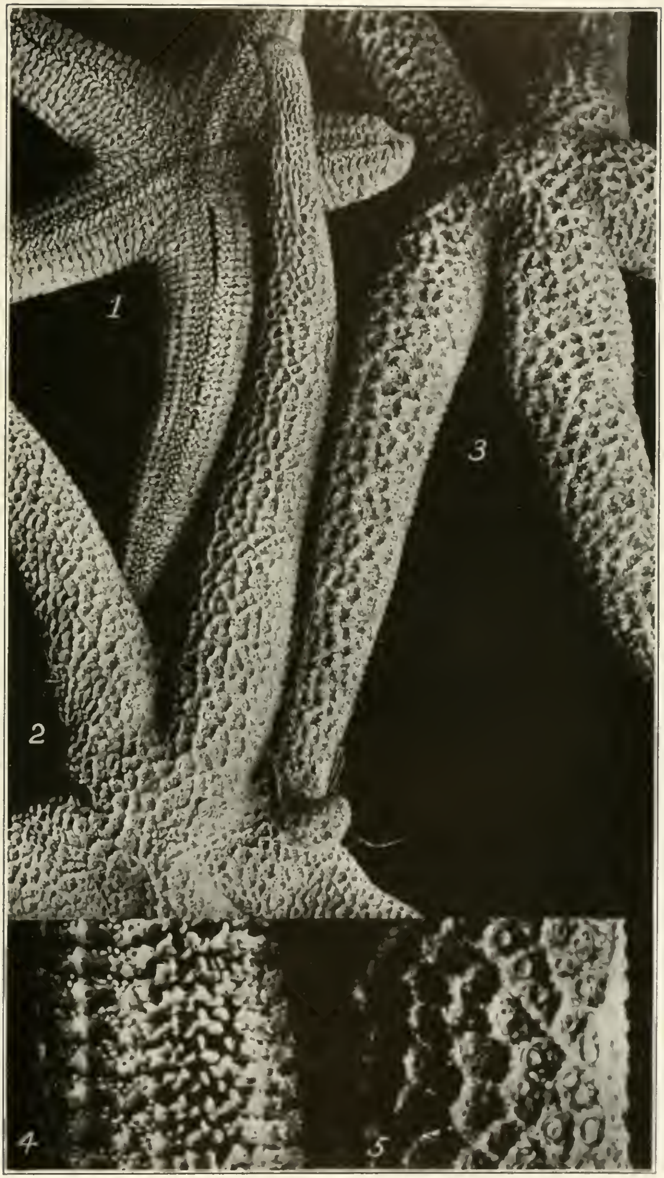
HENRICIA LEVIUSCULA MULTISPINA.

FOR EXPLANATION OF PLATE SEE PAGE 4[illegible]0.



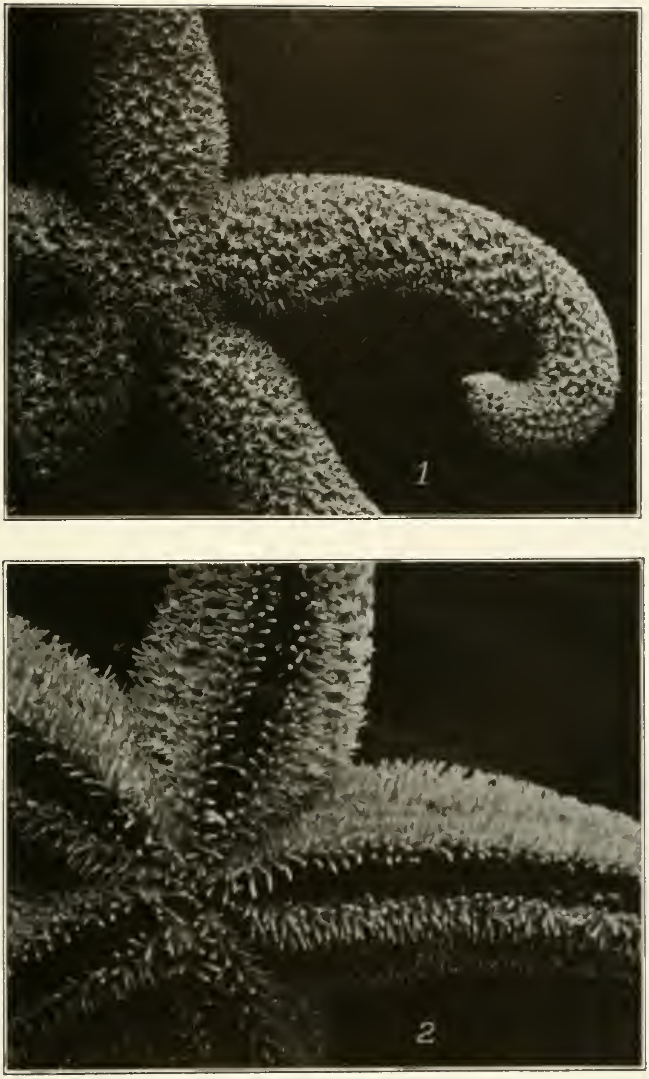
Henricia leviuscula dyscrita.

For explanation of plate see page 400.



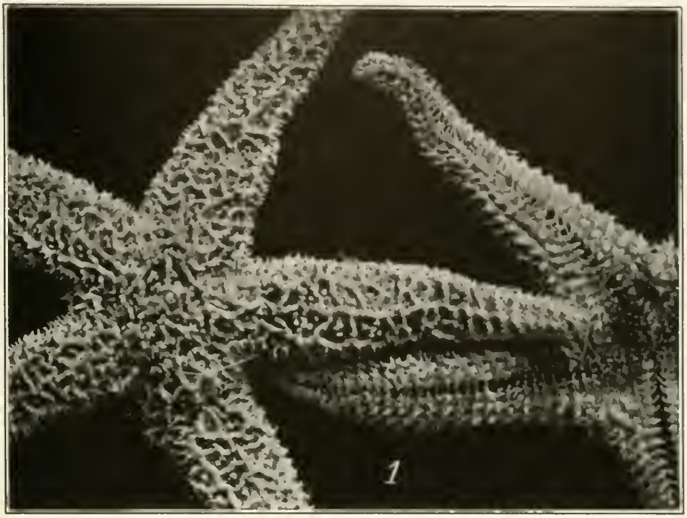
Henricia aspera.

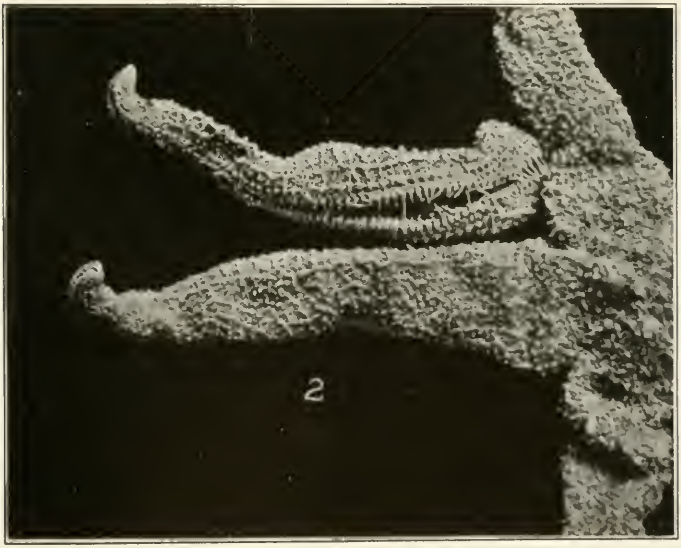
For explanation of plate see page 400.



HENRICIA LONGISPINA.

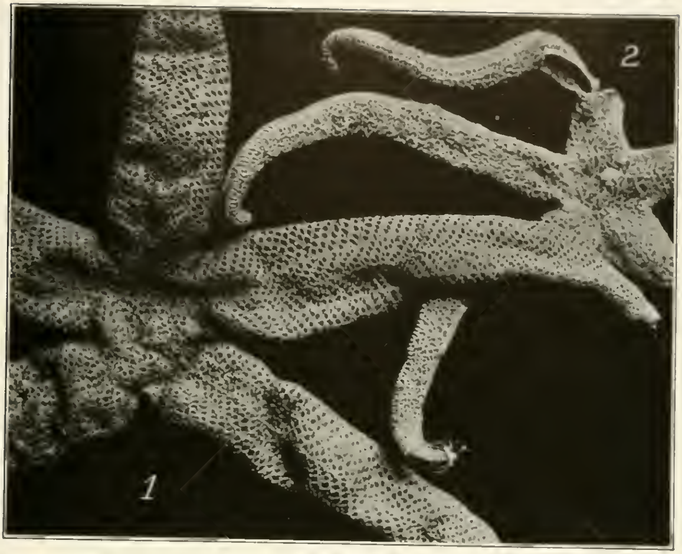
FOR EXPLANATION OF PLATE SEE PAGE 400.

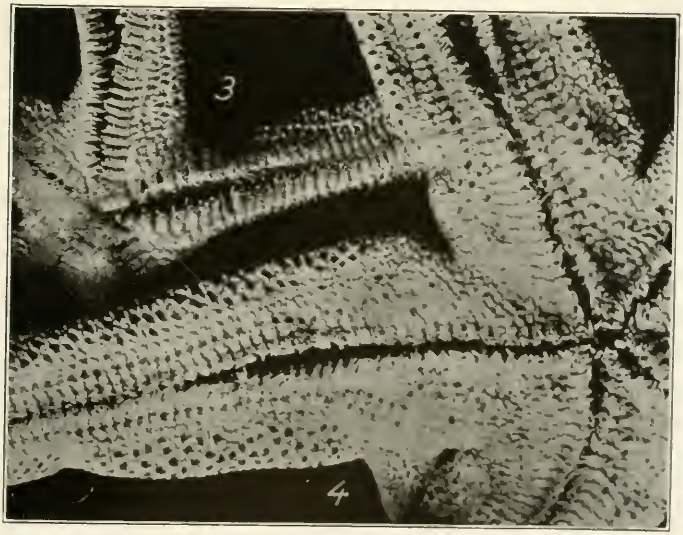




1. HENRICIA ASTHENACTIS. 2. H. LONGISPINA ALEUTICA.

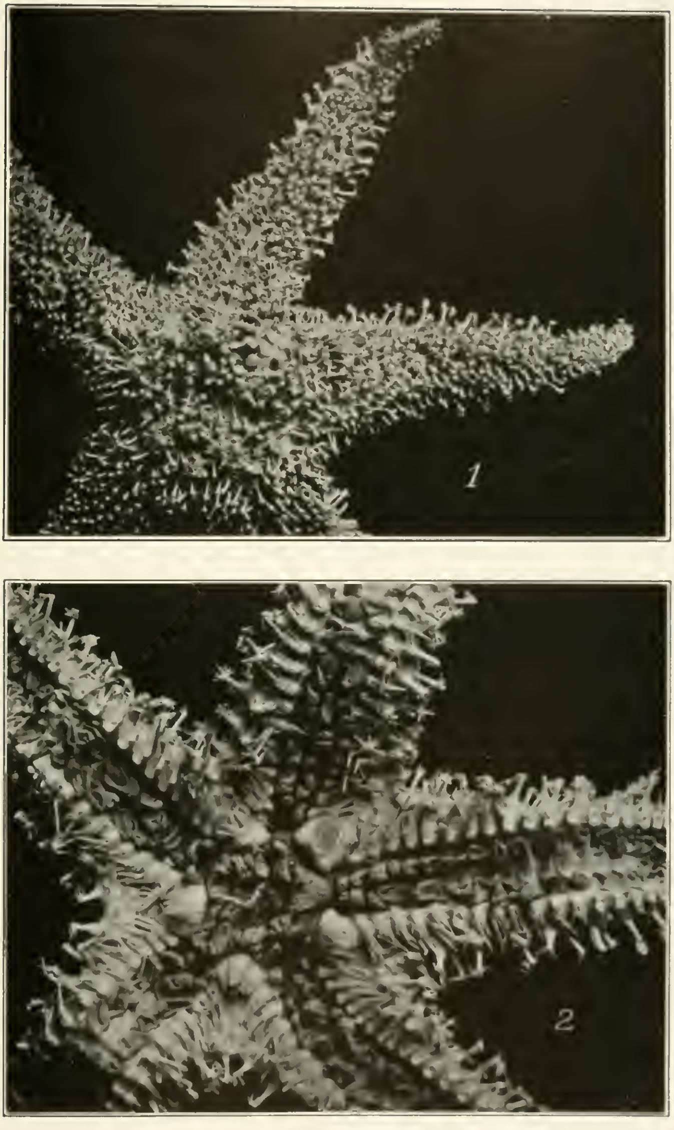
FOR EXPLANATION OF PLATE SEE PAGE 401





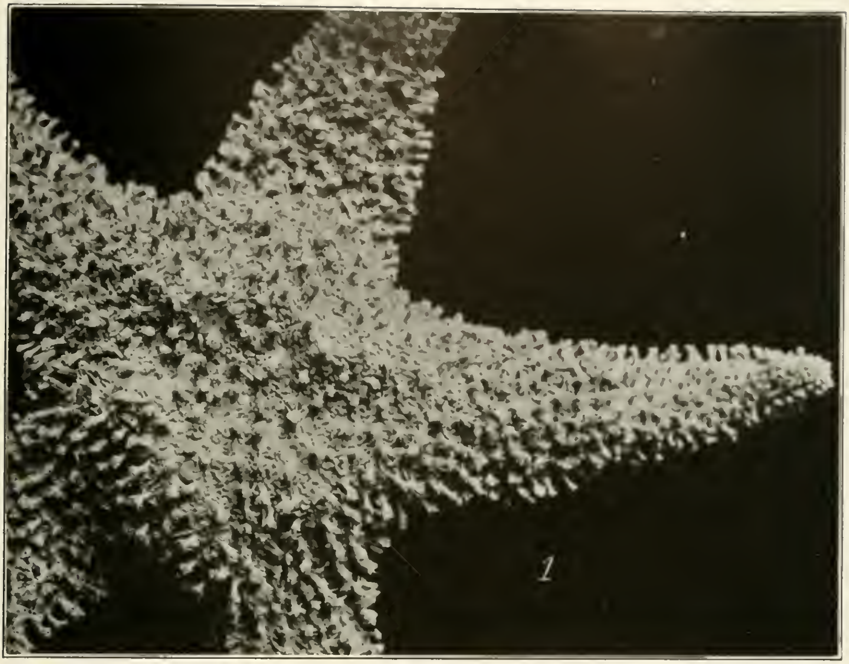
1, 4. HENRICIA POLYACANTHA. 2, 3. H. CLARKI.

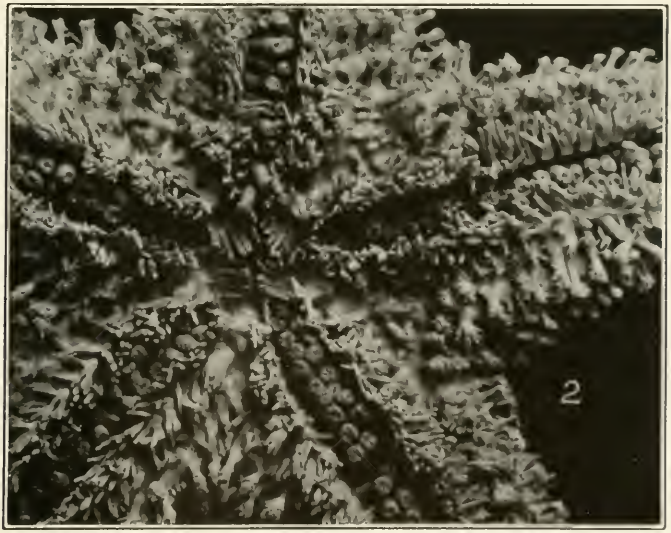
FOR EXPLANATION OF PLATE SEE PAGE 401.



Lophaster furcilliger.

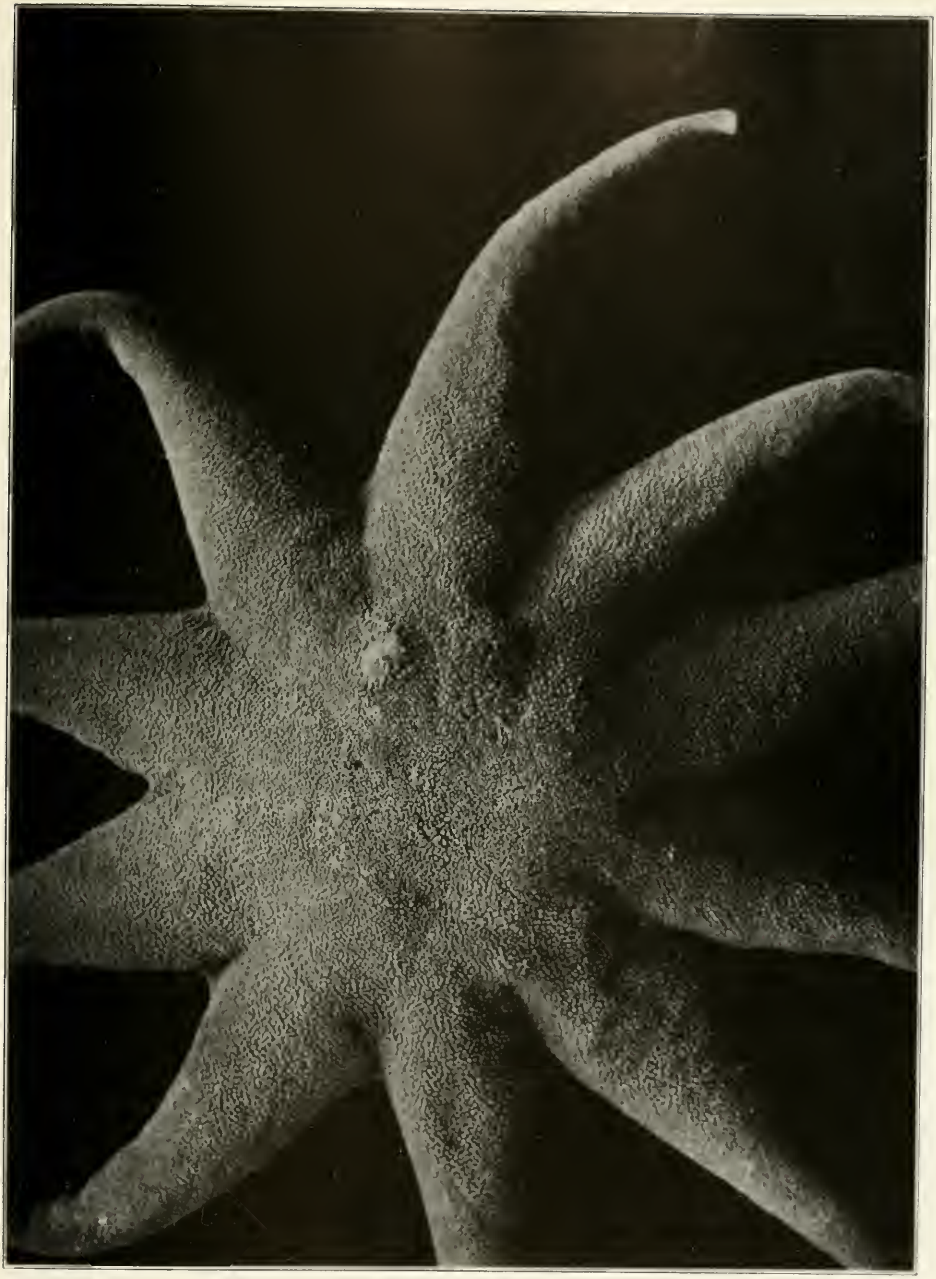
For explanation of plate see page 401.





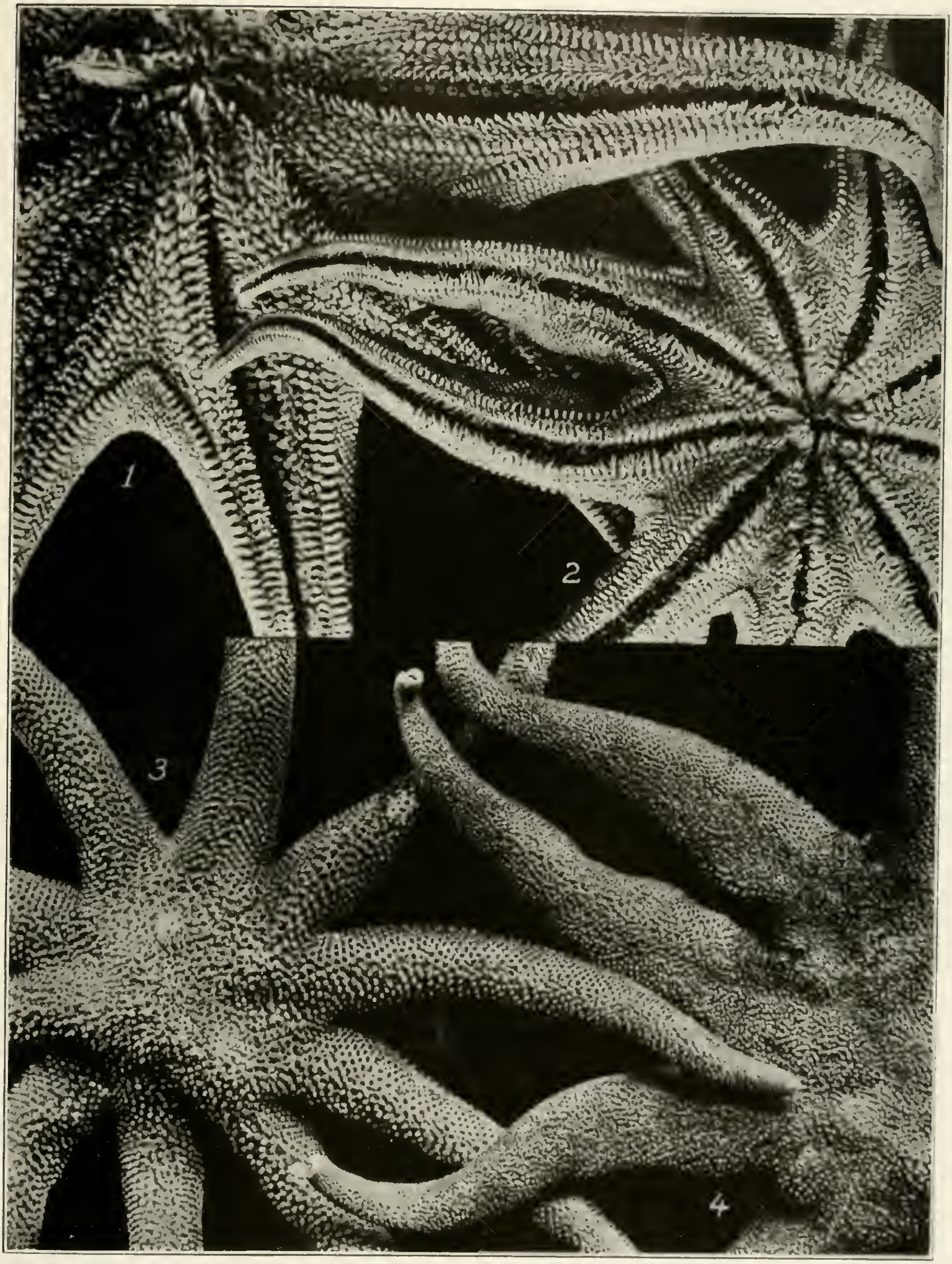
LOPHASTER FURCILLIGER VEXATOR.

FOR EXPLANATION OF PLATE SEE PAGE 401.



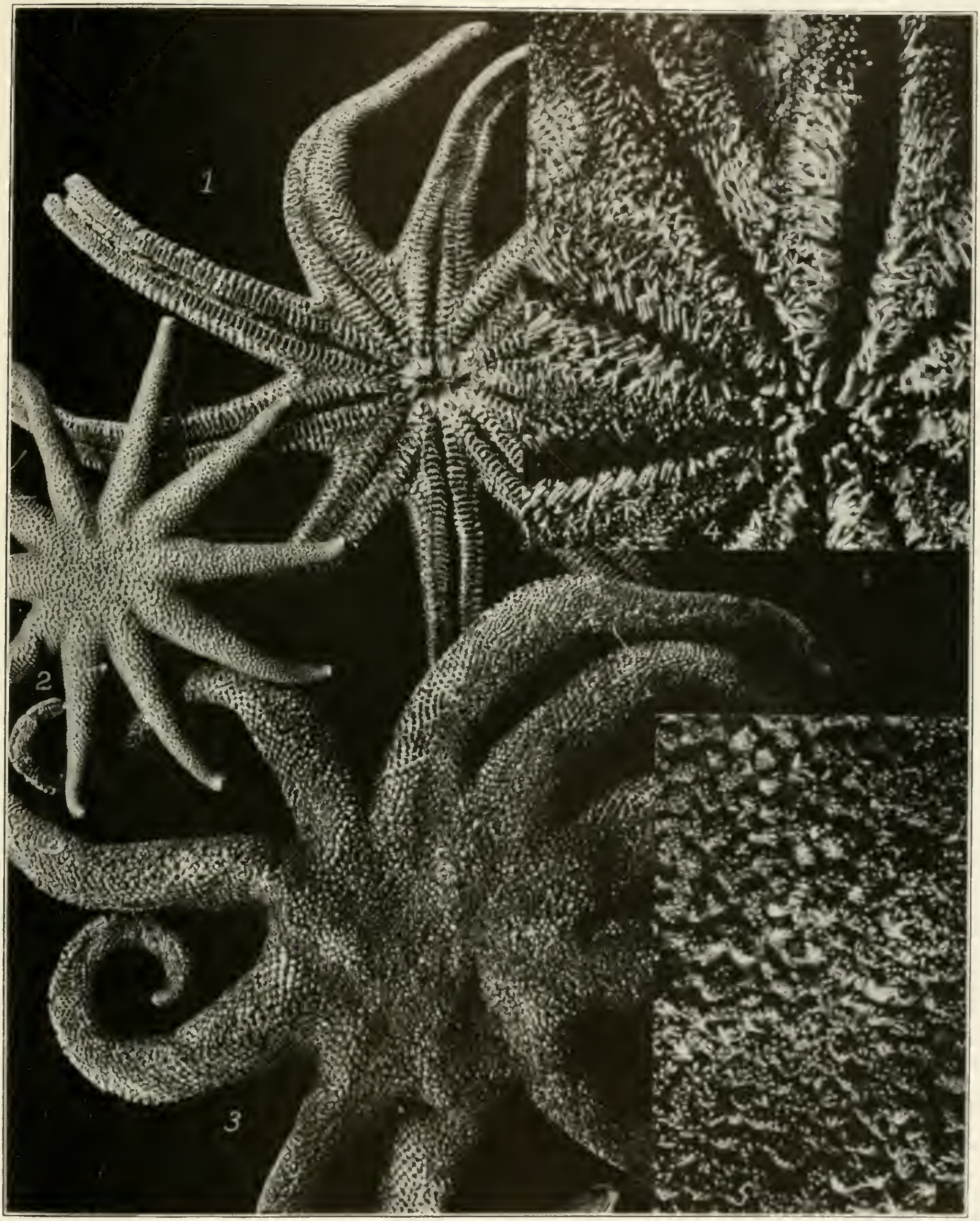
SOLASTER ENDECA

For explanation of plate see page 401.



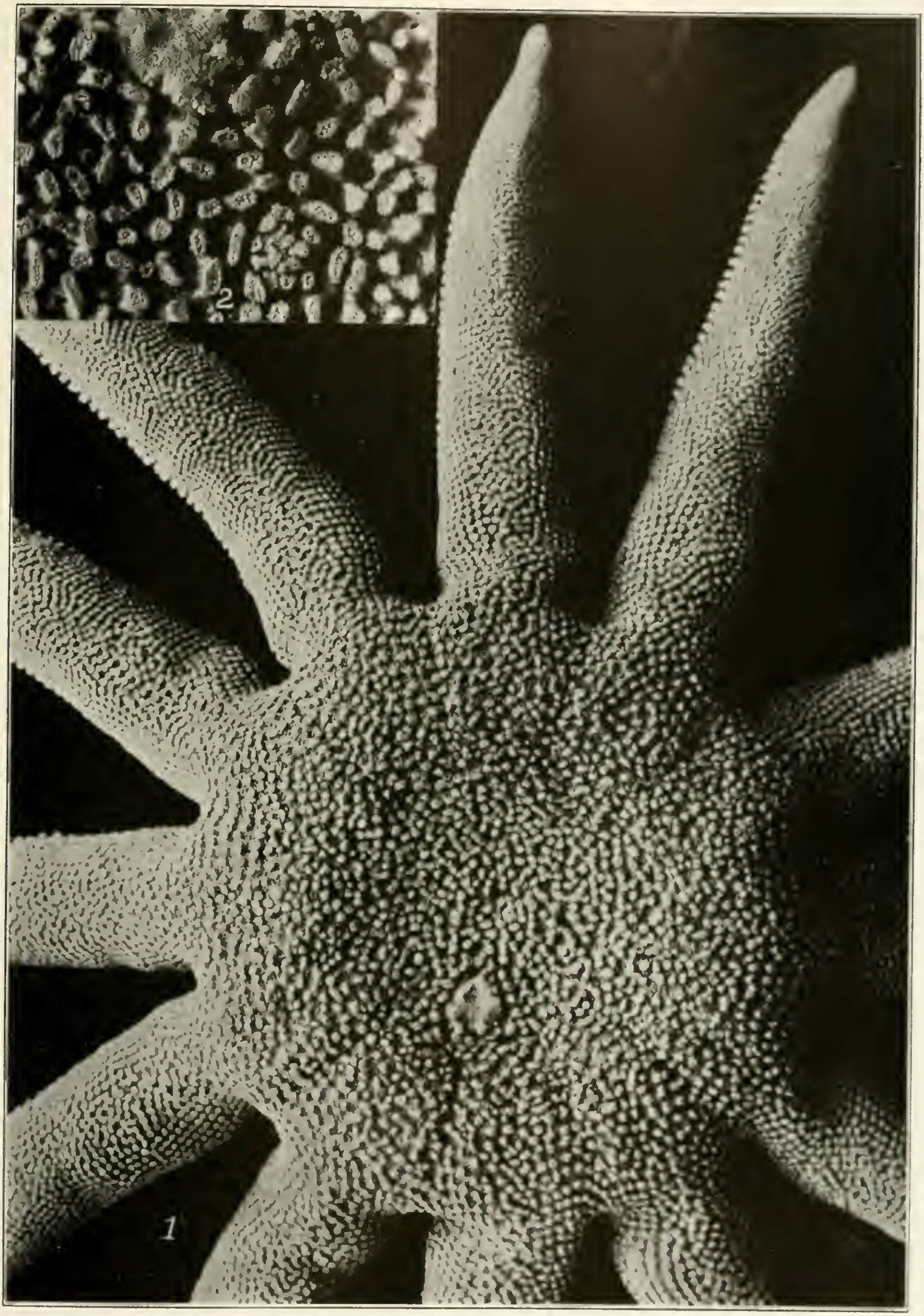
1, 2, 4. SOLASTER ENDECA. 3. S. STIMPSONI.

For explanation of plate see page 401.



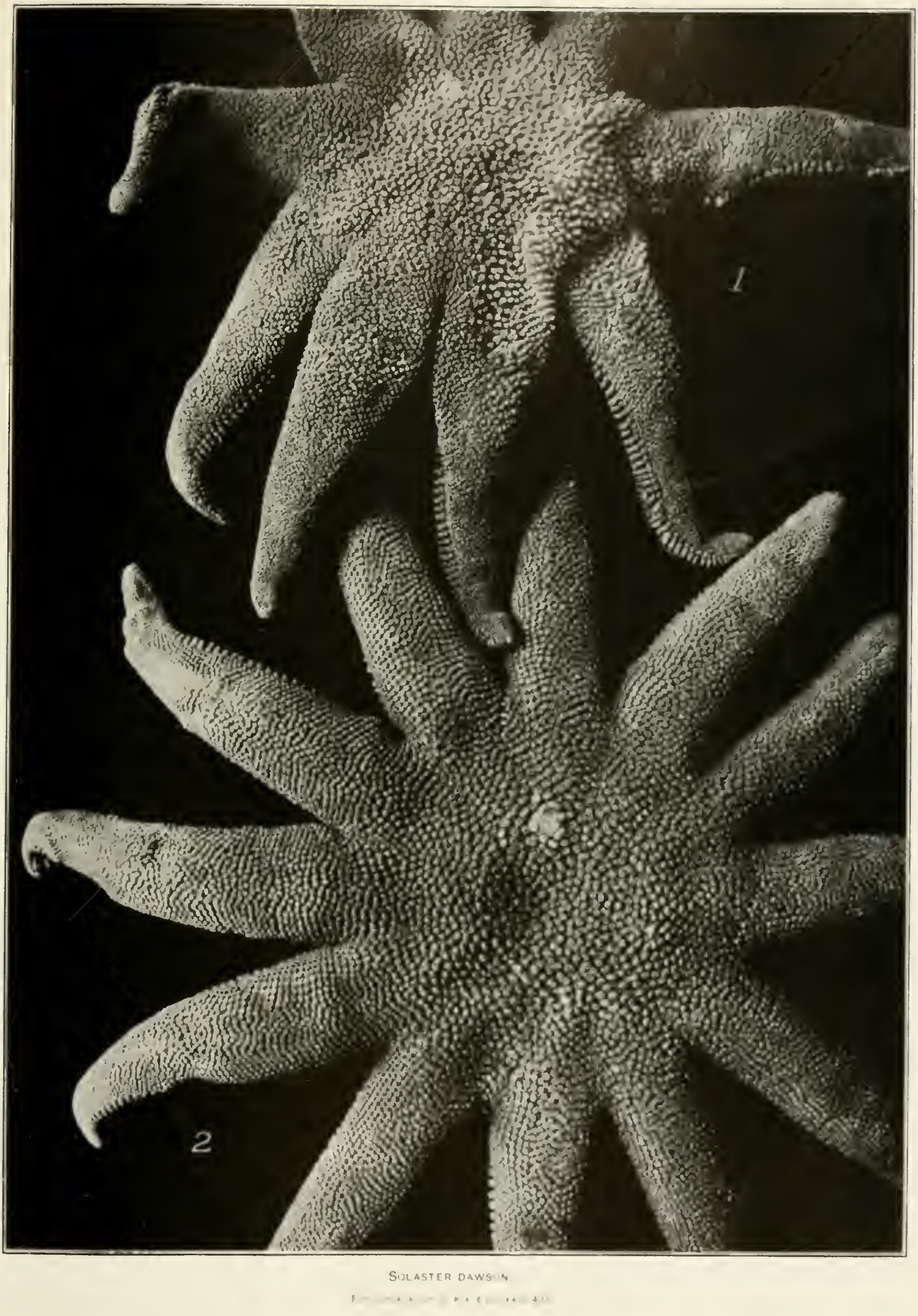
SOLASTER STIMPSONI

FOR EXPLANATION OF PLATE SEE PAGE 4[illegible]1



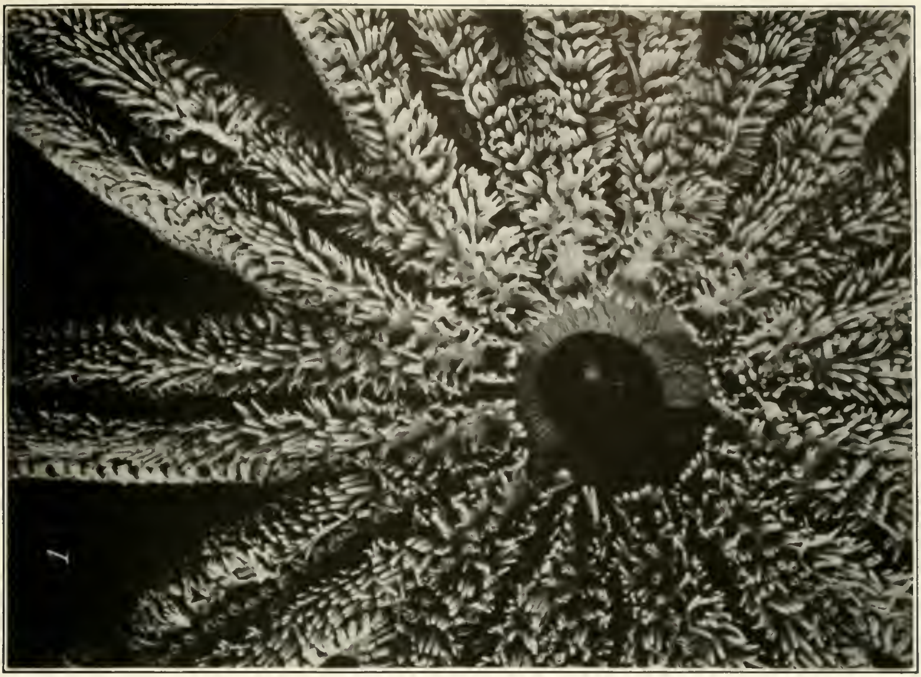
SOLASTER DAWSONI

For explanation of plate see page 4[illegible]1.



SOLASTER DAWSONI

[illegible]



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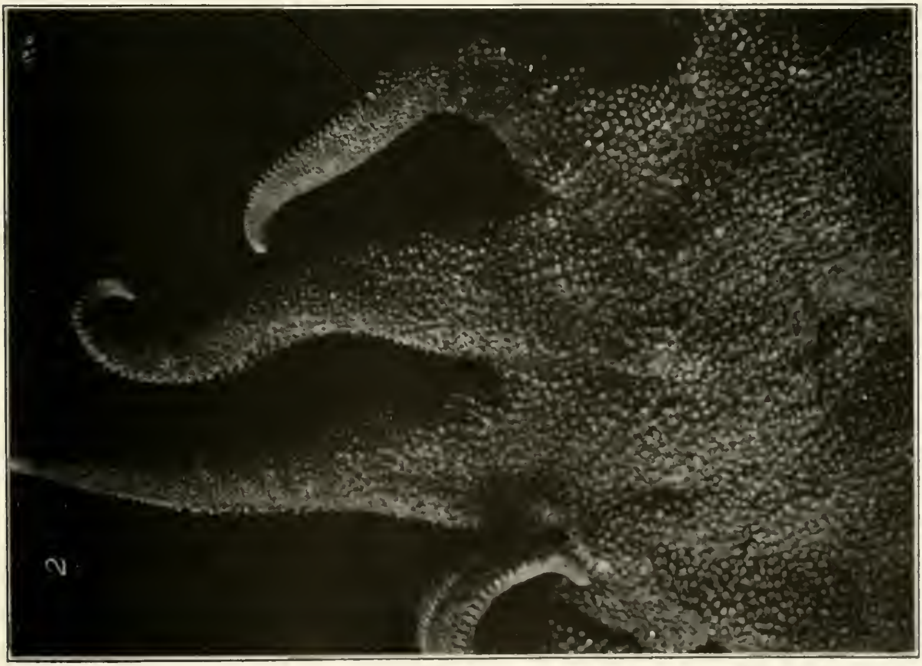

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SOLASTER DAWSONI

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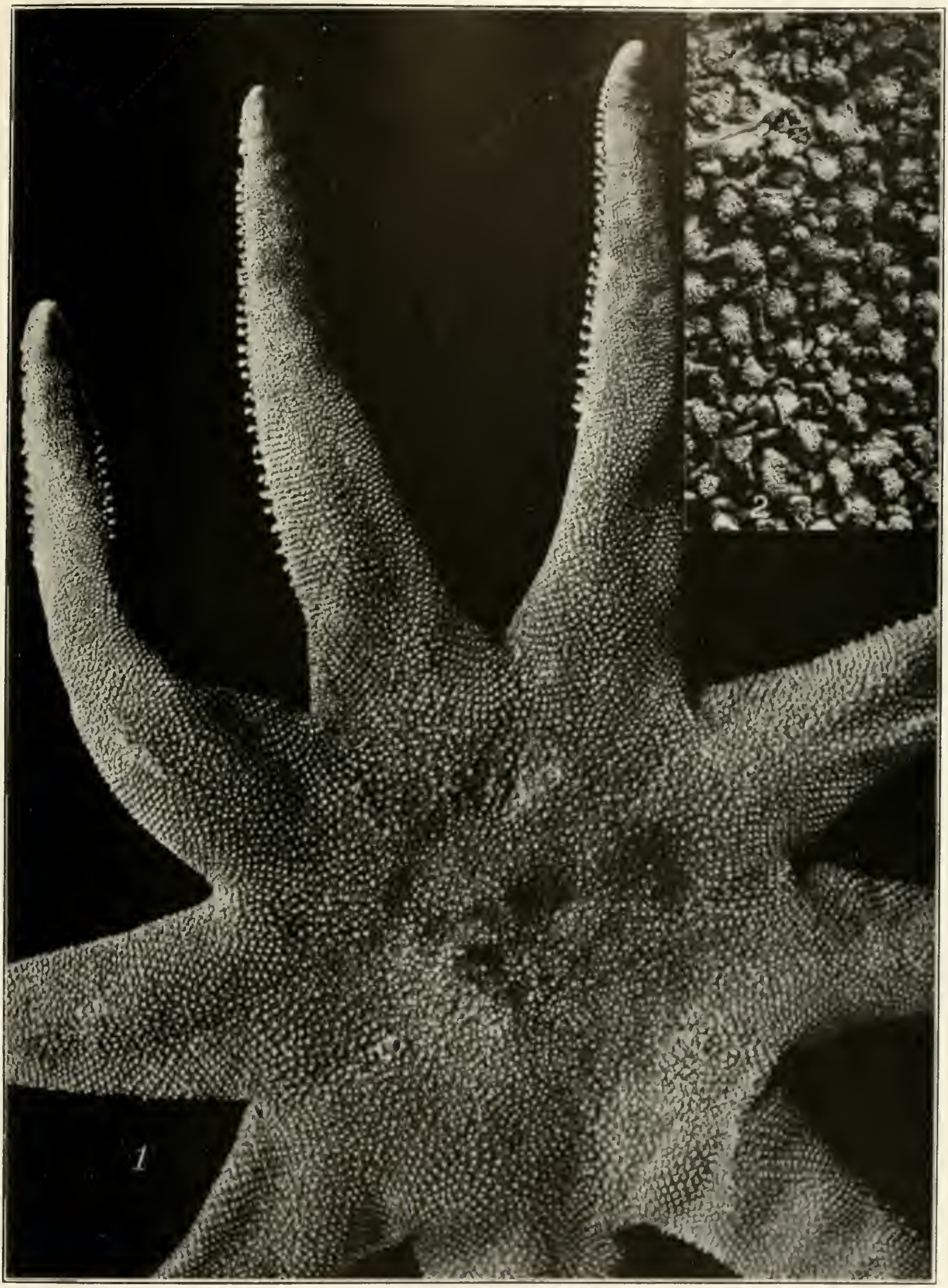
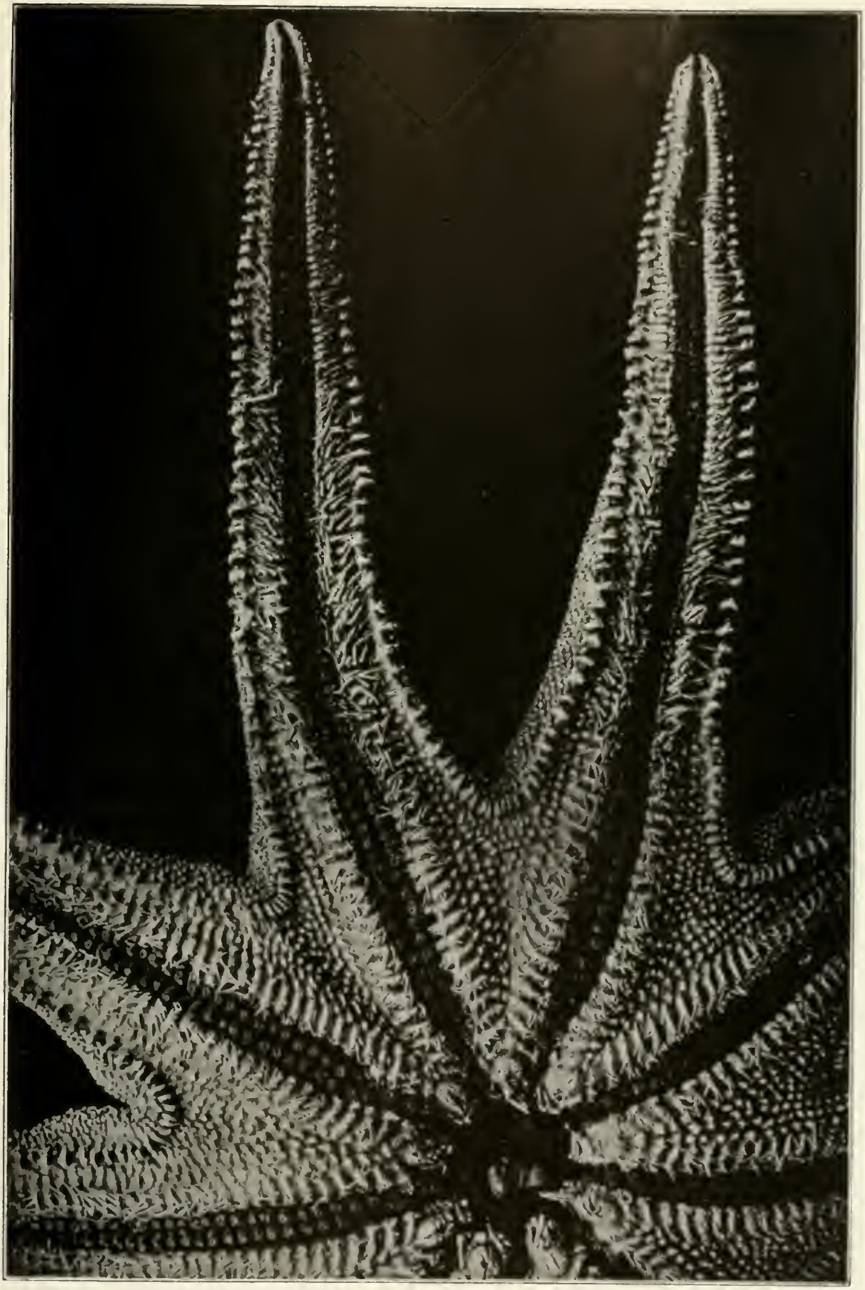


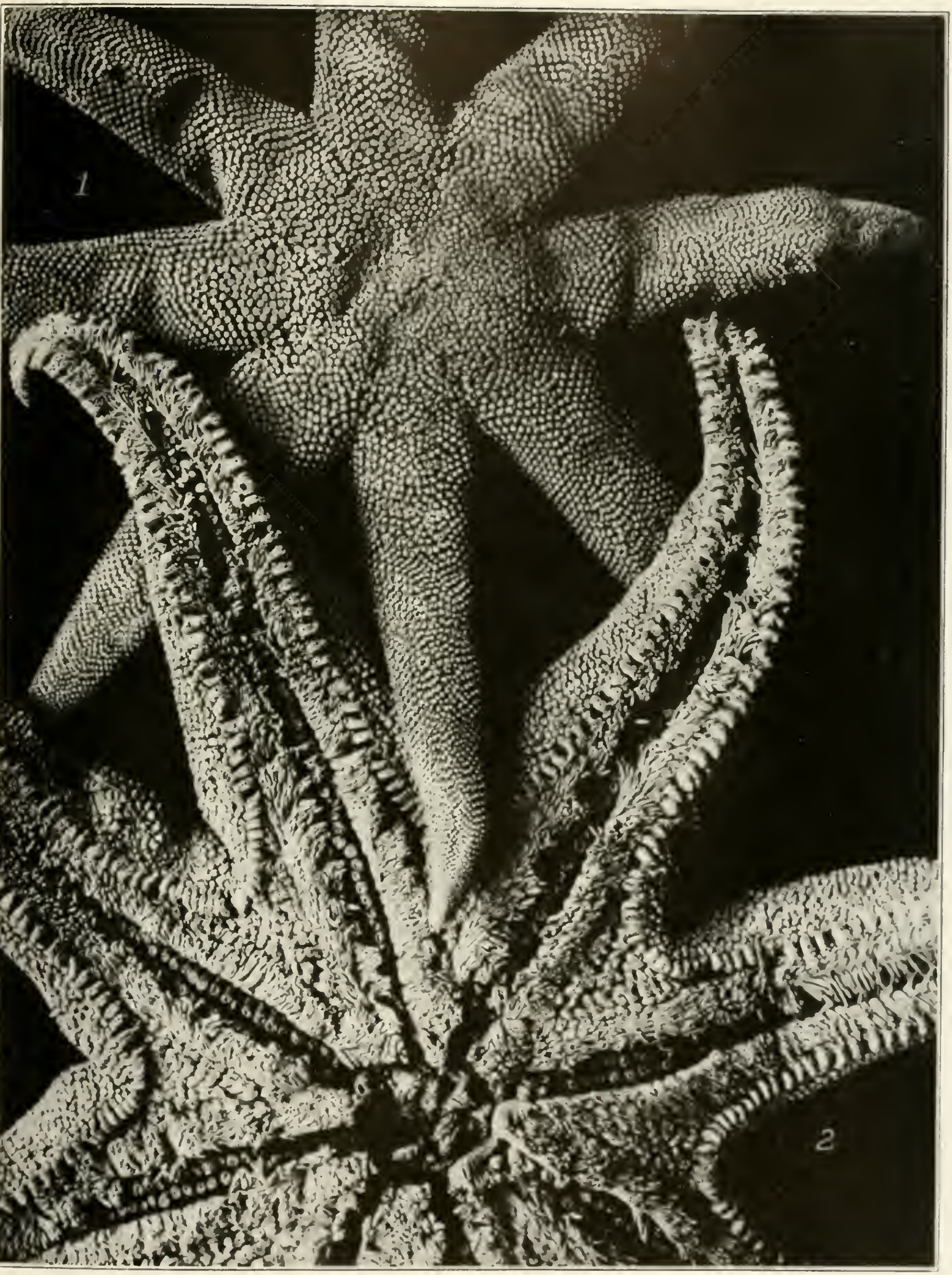
SOLASTER PAXILLATUS.

FOR EXPLANATION OF PLATE SEE PAGE 4[illegible]



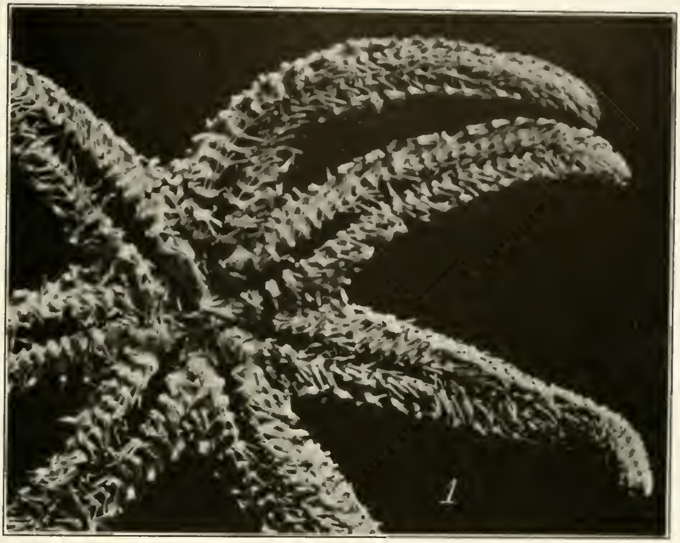
SOLASTER PAXILLATUS.

FOR EXPLANATION OF PLATE SEE PAGE 401.



SOLASTER PAPILLATUS, VARIETY.

For explanation of plate see page 412.



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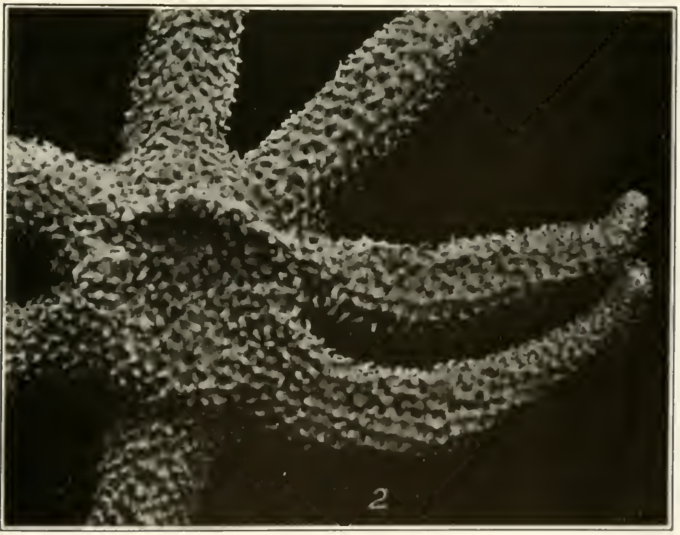
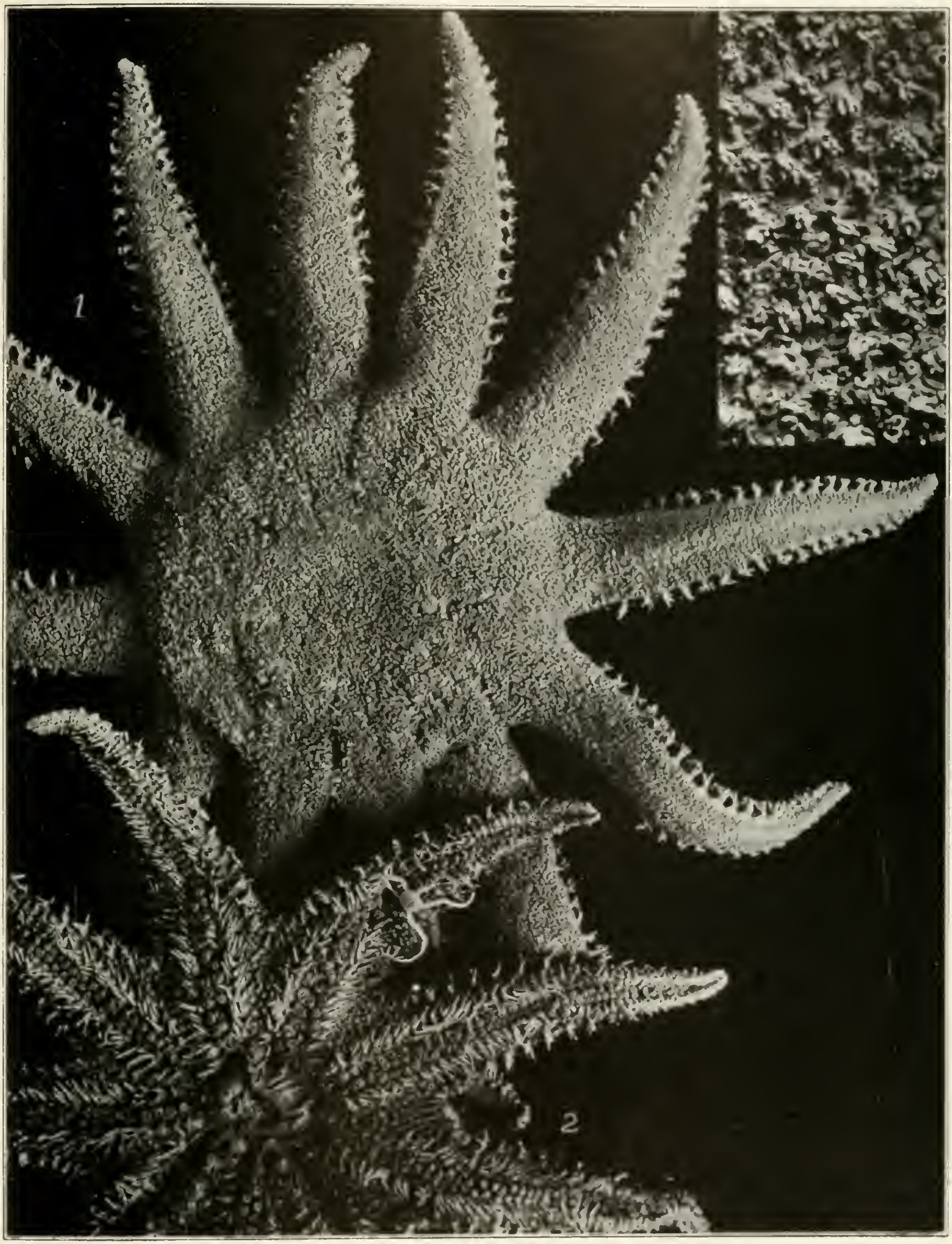


2

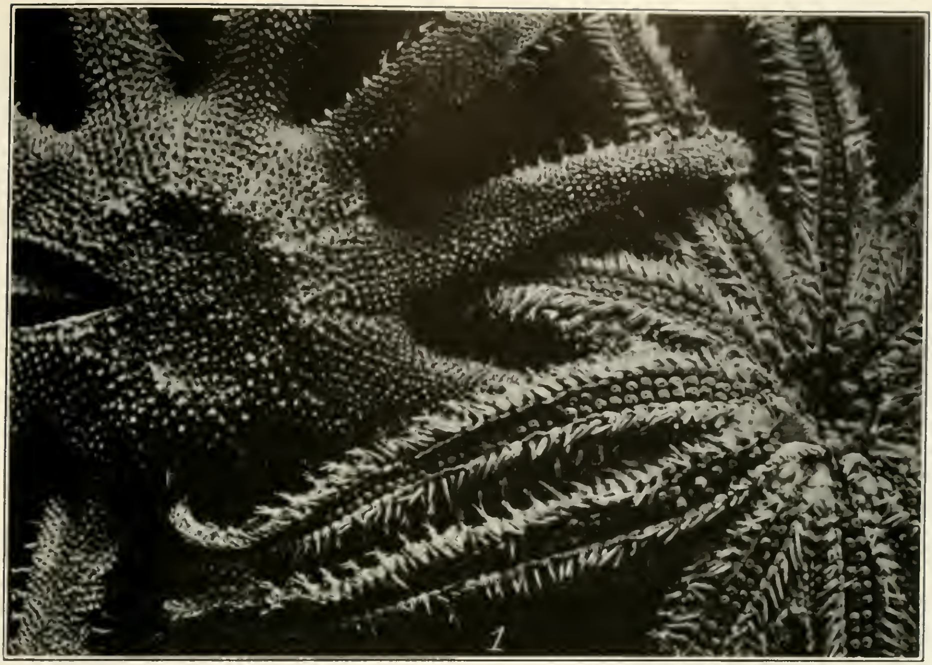
SOLASTER EXIGUUS.

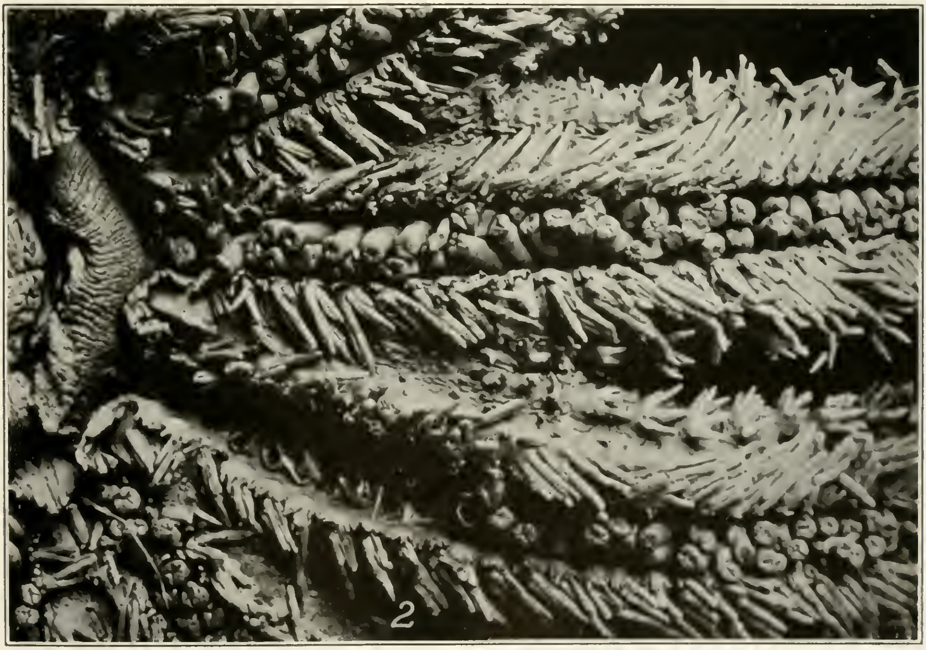
FOR EXPLANATION OF PLATE SEE PAGE 402.



SOLASTER BOREALIS.

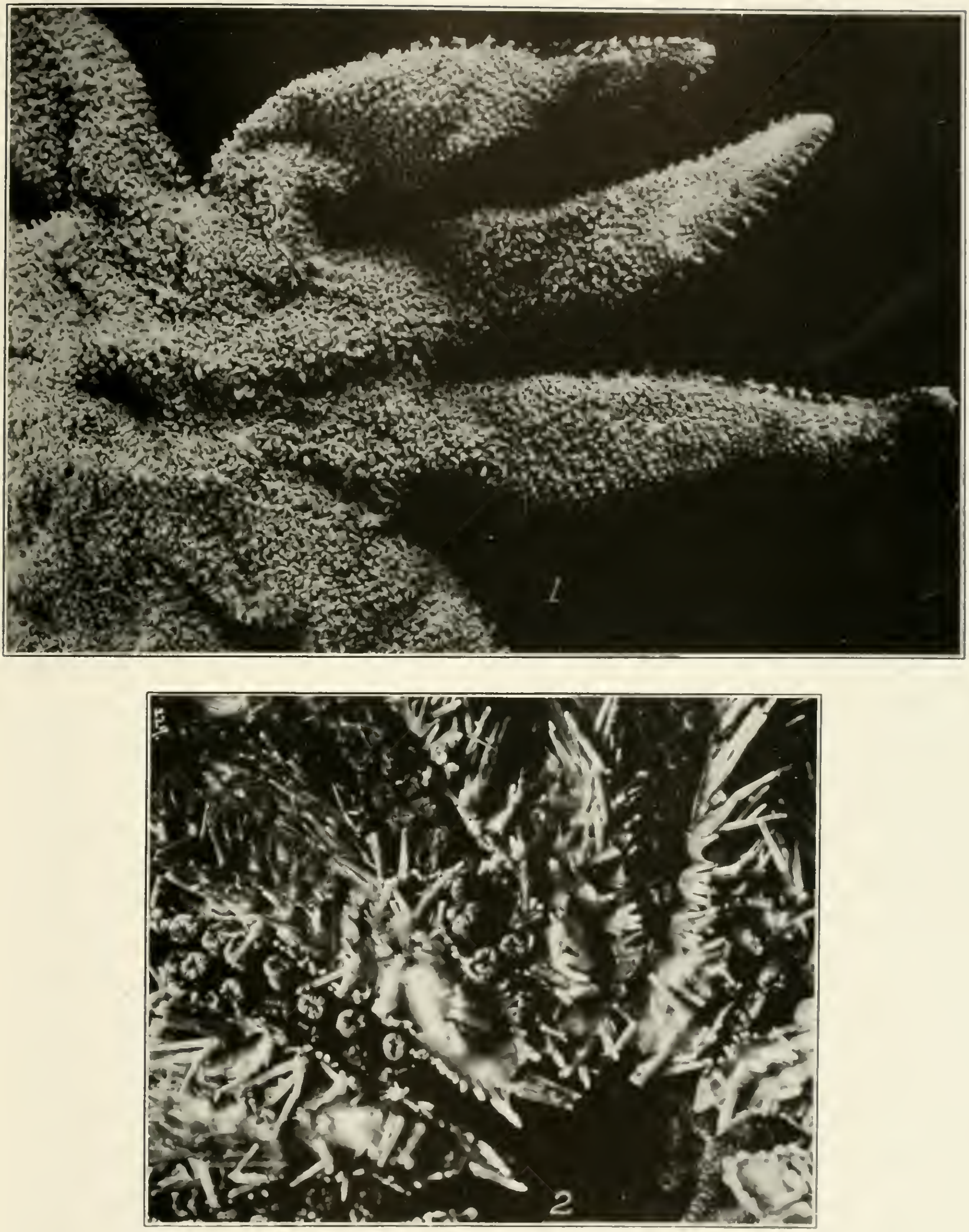
For explanation of plate see page [illegible]





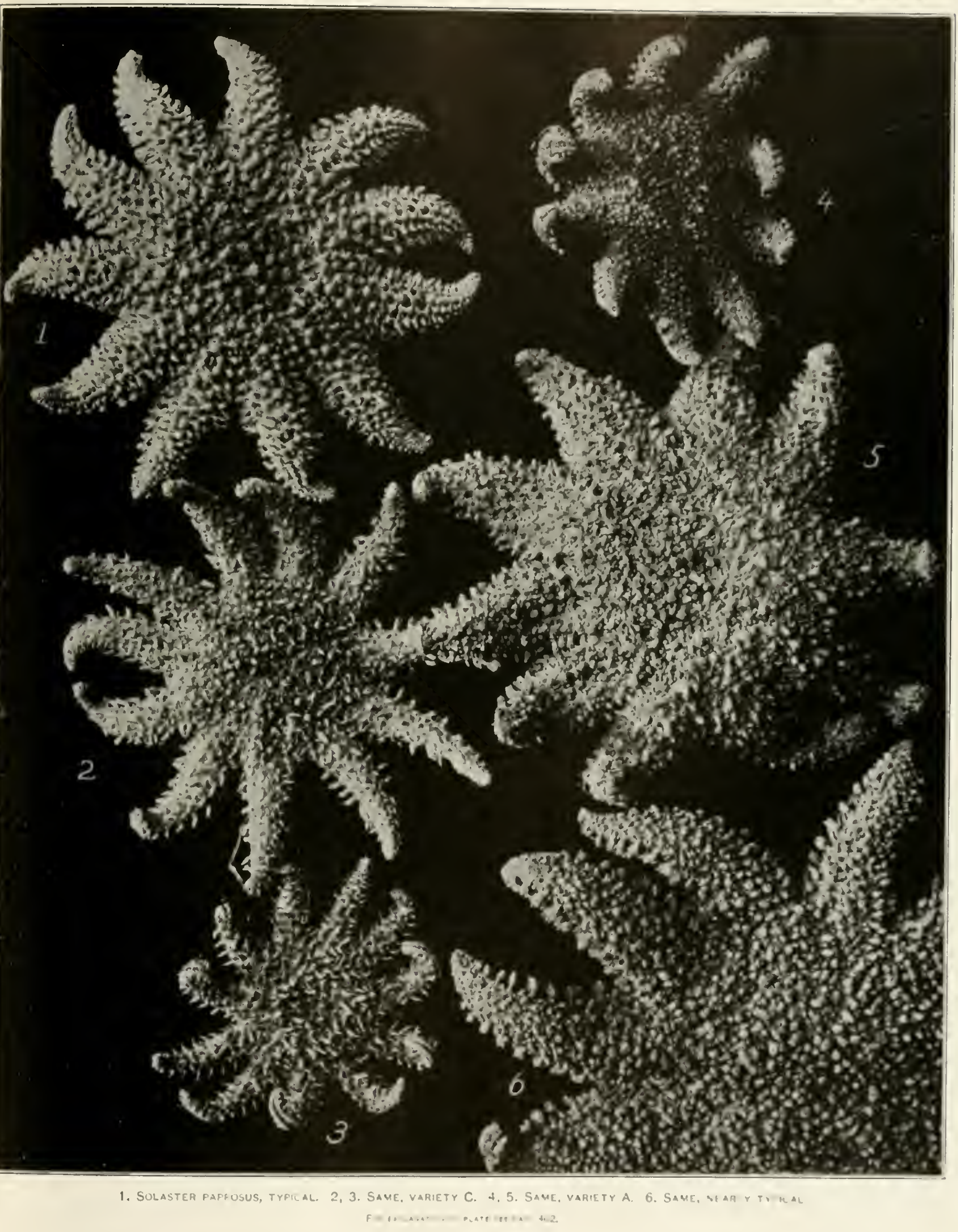
1. Solaster borealis, variety. 2. S. borealis, typical.

For explanation of plate see page 4[illegible]



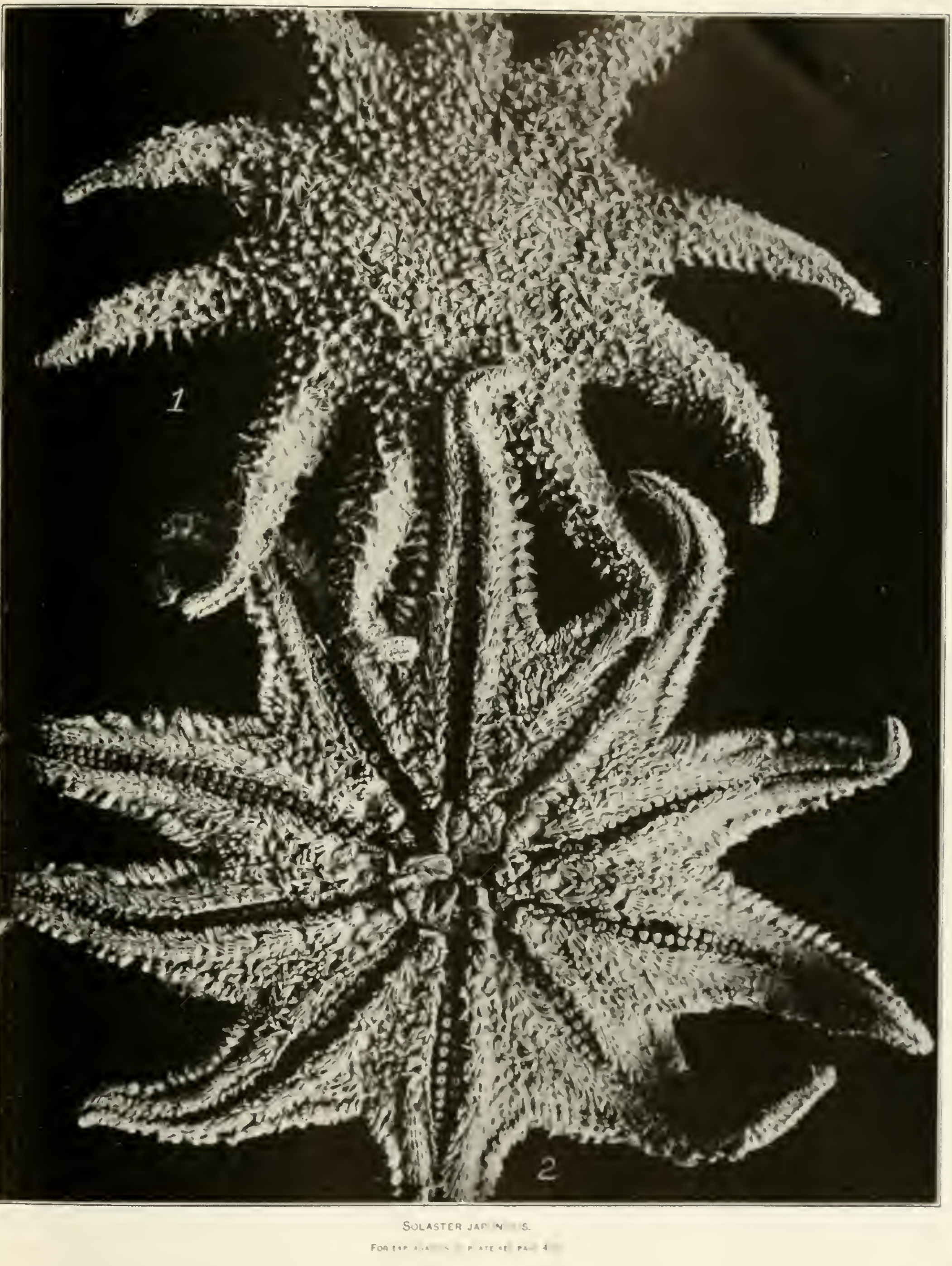
SOLASTER HYPOTHRISSUS

For explanation of plate see page 4[illegible]



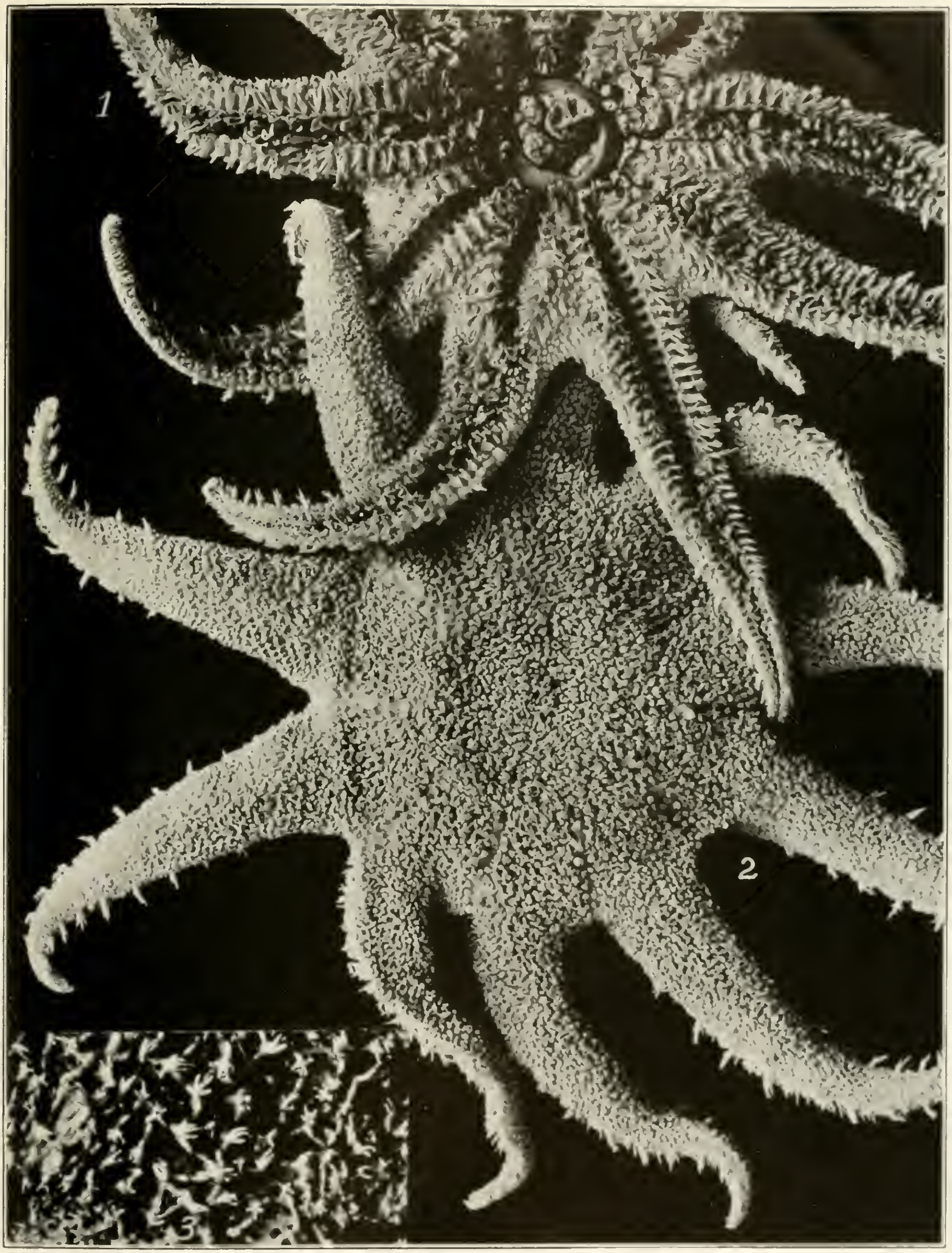
1. Solaster papposus, typical. 2, 3. Same, variety C. 4, 5. Same, variety A. 6. Same, nearly typical.

For explanation of plate see page 4[illegible]2.



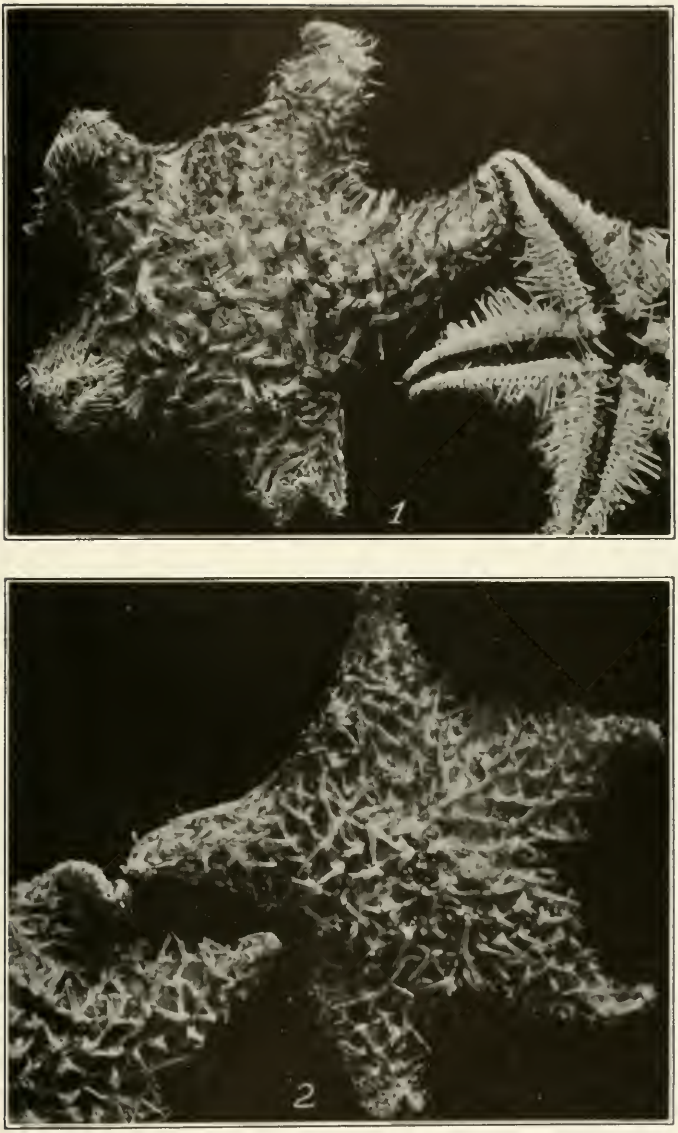
Solaster japonicus.

For explanation of plate see page 4[illegible]



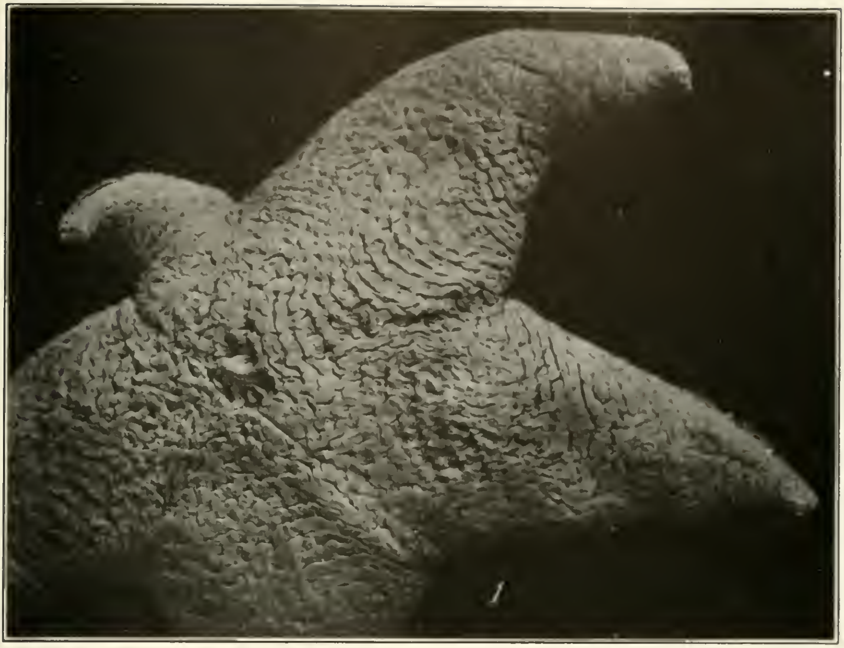
HETEROZONIAS ALTERNATUS.

FOR EXPLANATION OF PLATE SEE PAGE 402.



PERIBULASTER BISERIALIS.

FOR EXPLANATION OF PLATE SEE PAGE 402.



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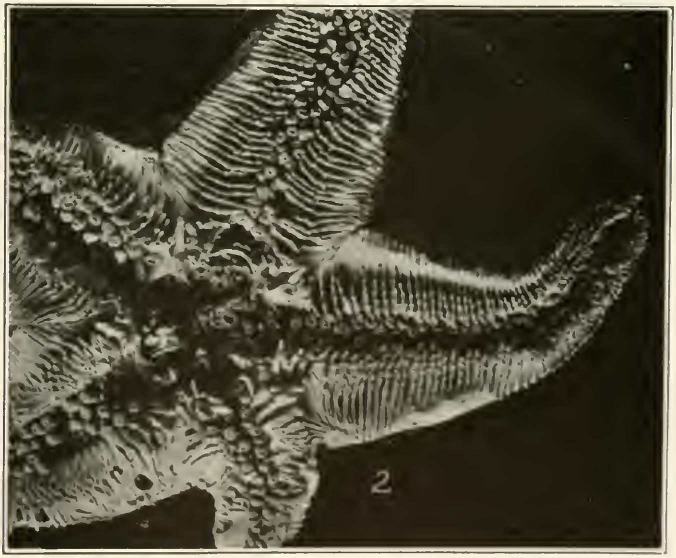

2

PTERASTER MILITARIS.

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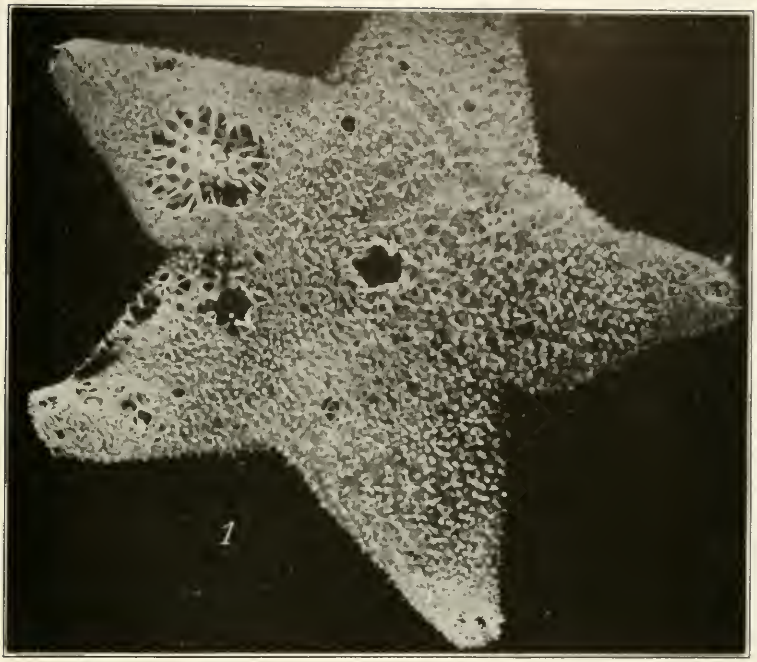

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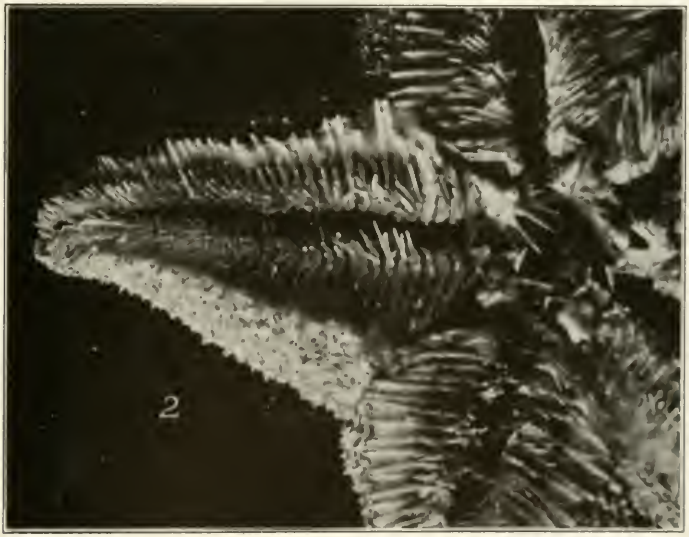

2

PTERASTER TRIGONODON

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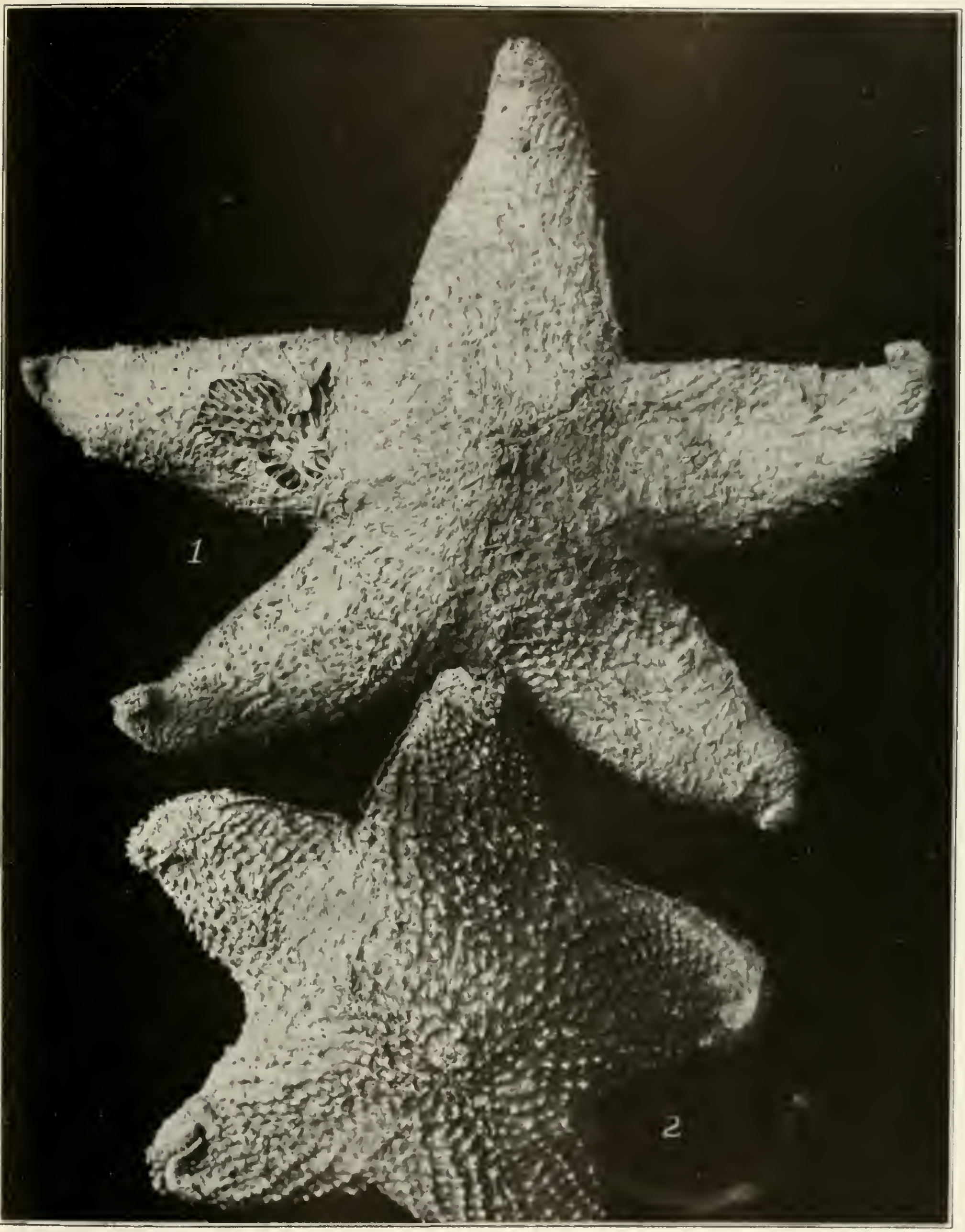
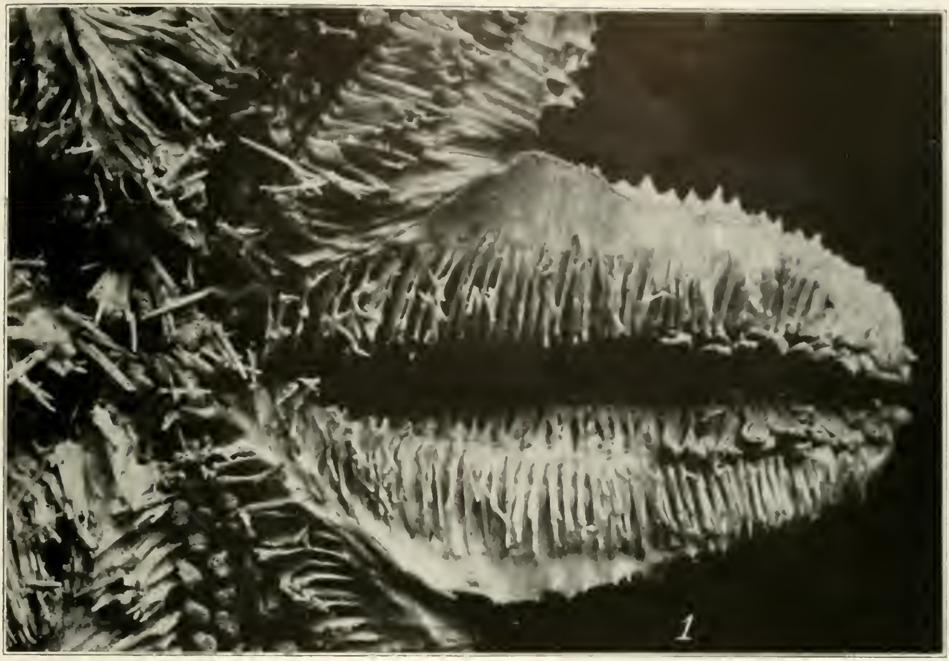
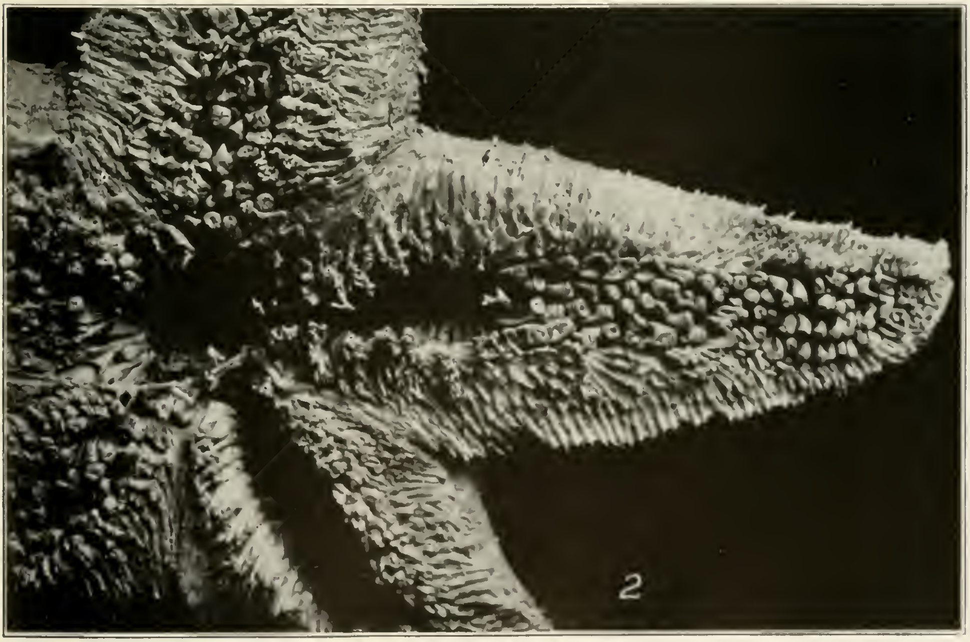


1. PTERASTER MARSIPPUS. 2. PT. JORDAN

FOR EXPLANATION OF PLATE SEE PAGE 413.





1. PTERASTER JORDANI. 2. PT. MARSIPPUS.

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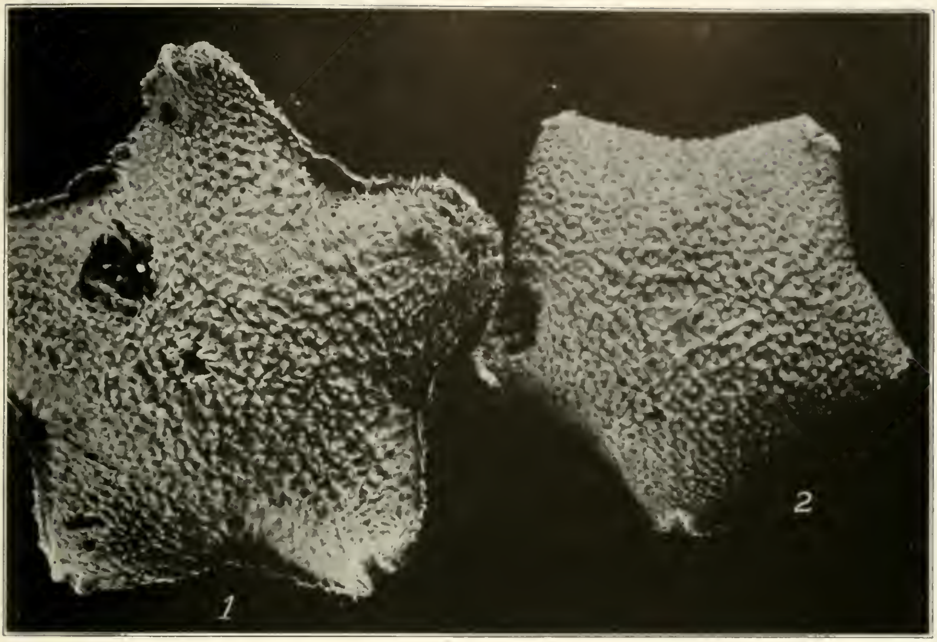
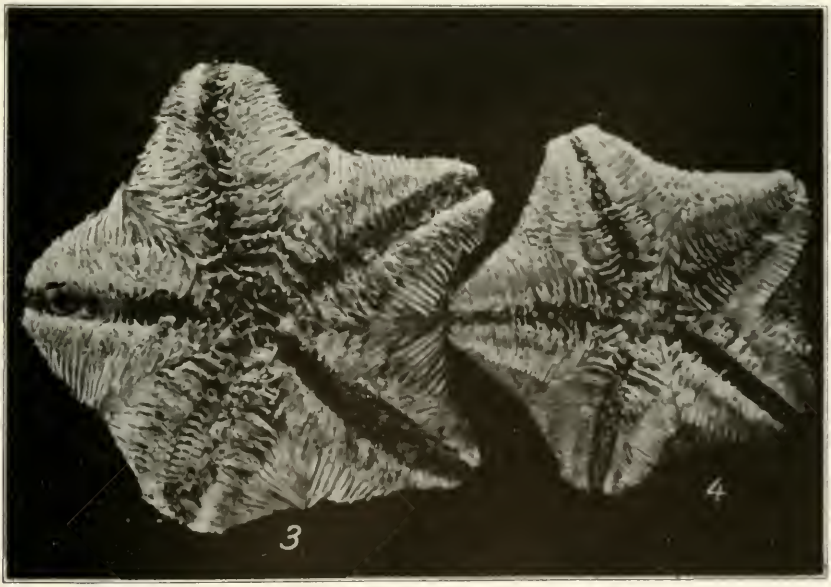
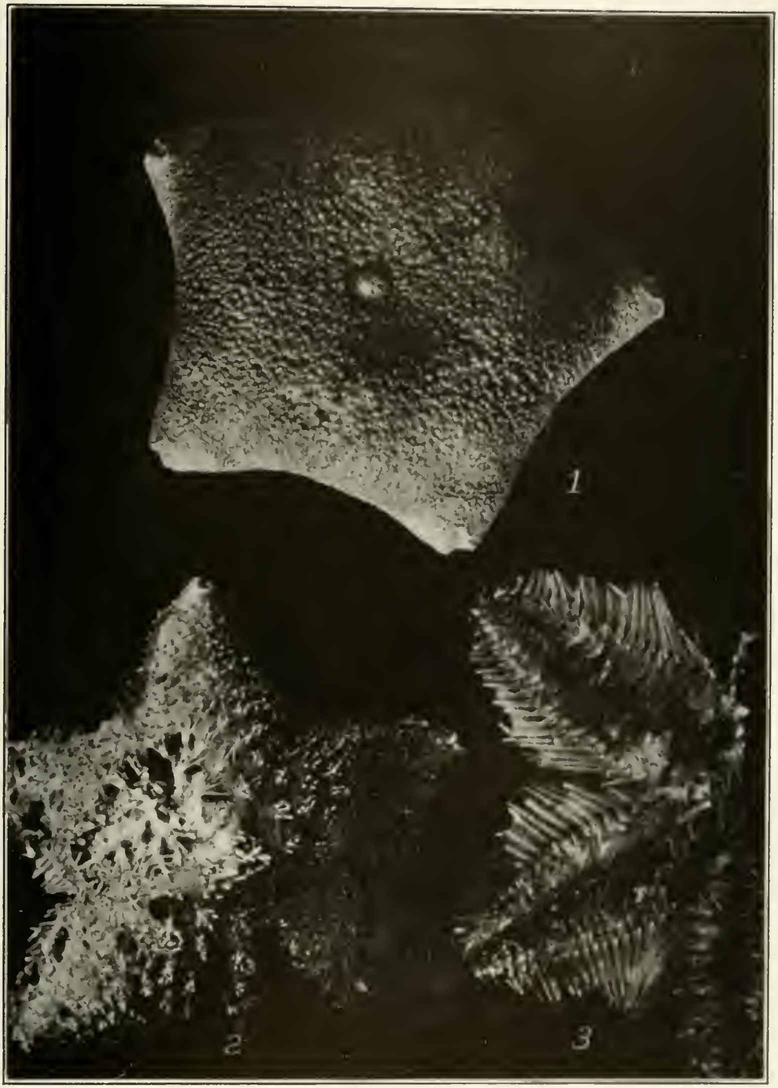




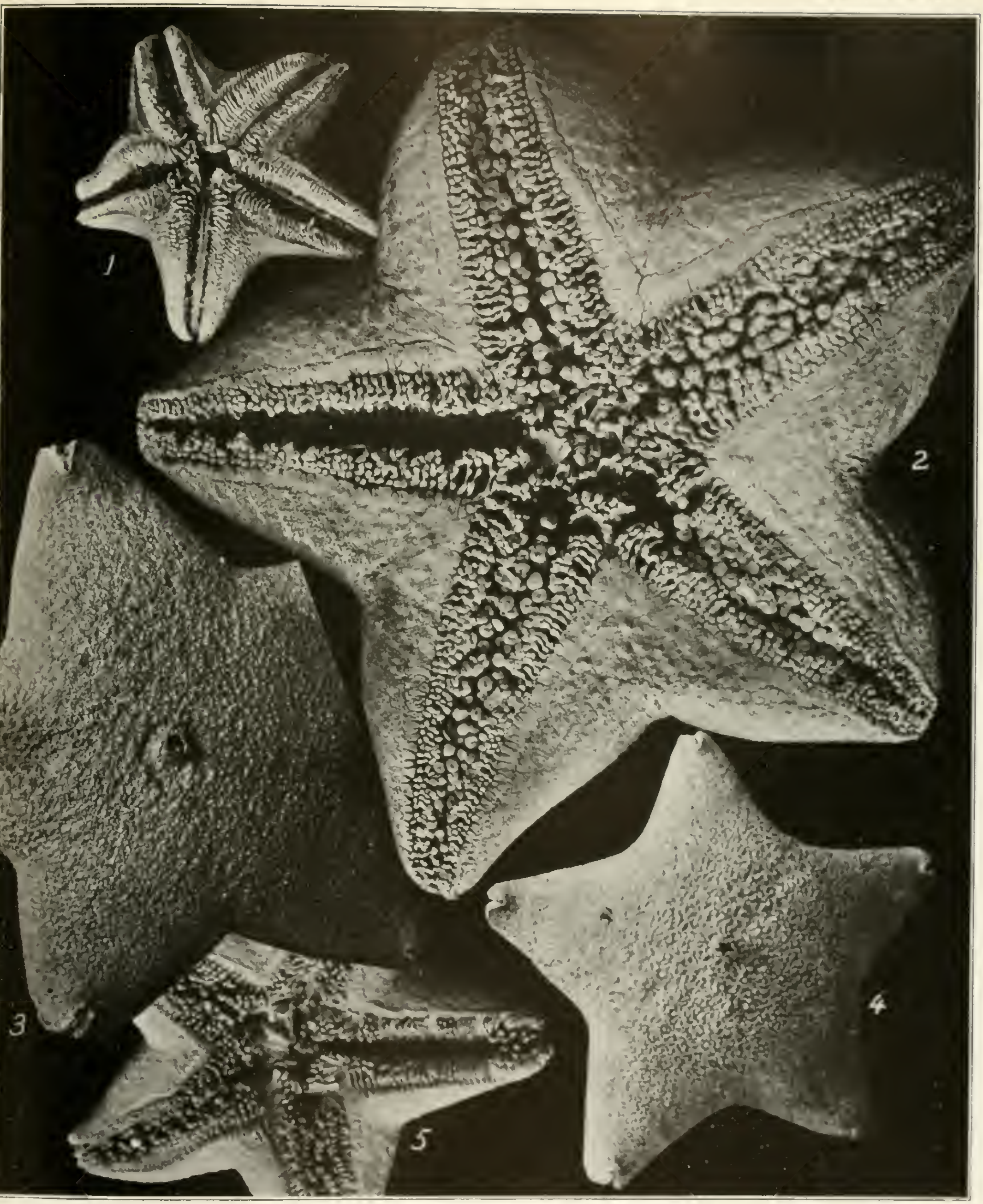
1, 3. PTERASTER COSCINOPEPLUS. 2, 4. PT. PULVILLUS.

FOR EXPLANATION OF PLATE SEE PAGE 403



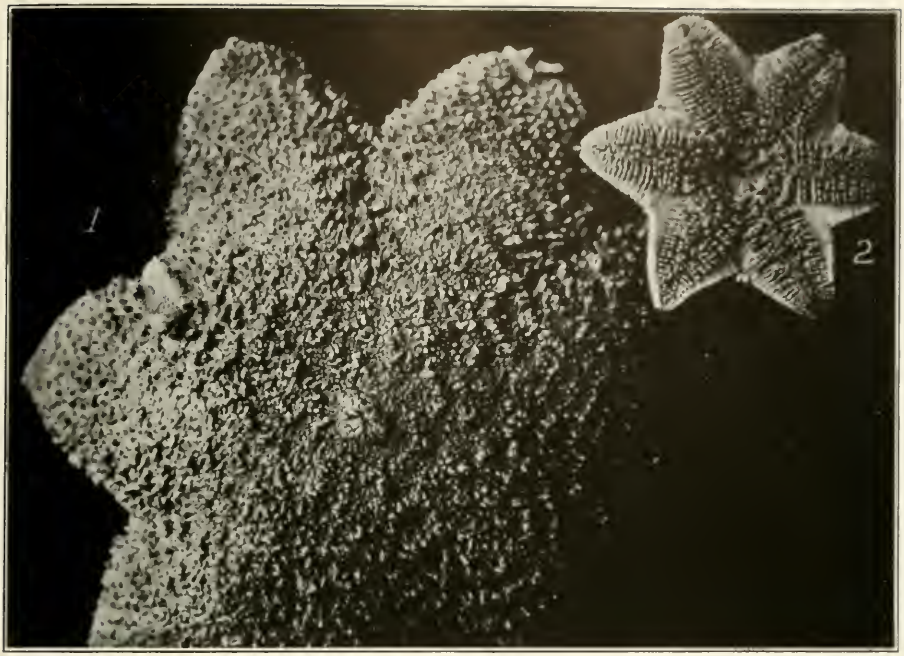
1. PTERASTER TESSELATUS ARCUATUS. 2, 3. P. TEMNOCHITON.

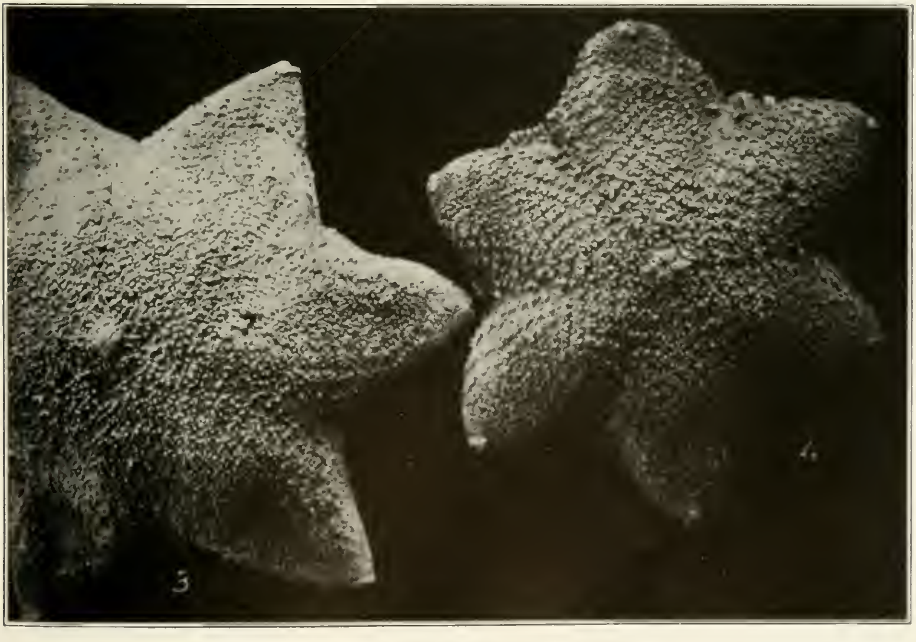
FOR EXPLANATION OF PLATE SEE PAGE 403.



PTERASTER TESSELATUS.

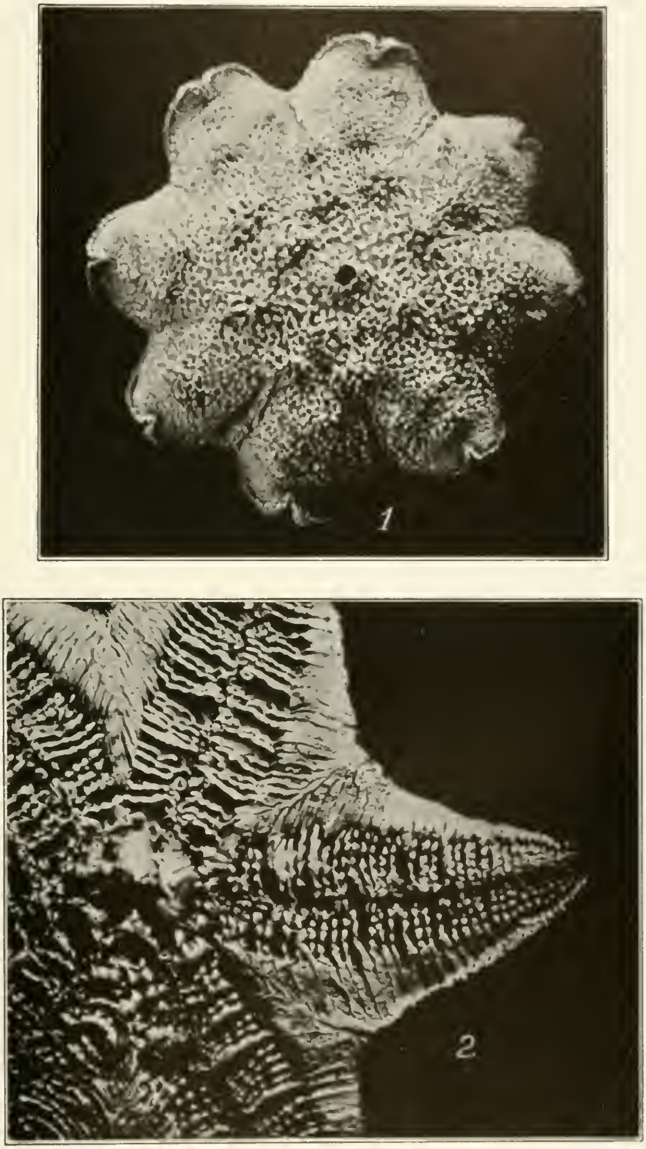
FOR EXPLANATION OF PLATE SEE PAGE 4[illegible]3.





PTERASTER OBSCURUS.

For explanation of plate see page 403.



PTERASTER OBSCURUS

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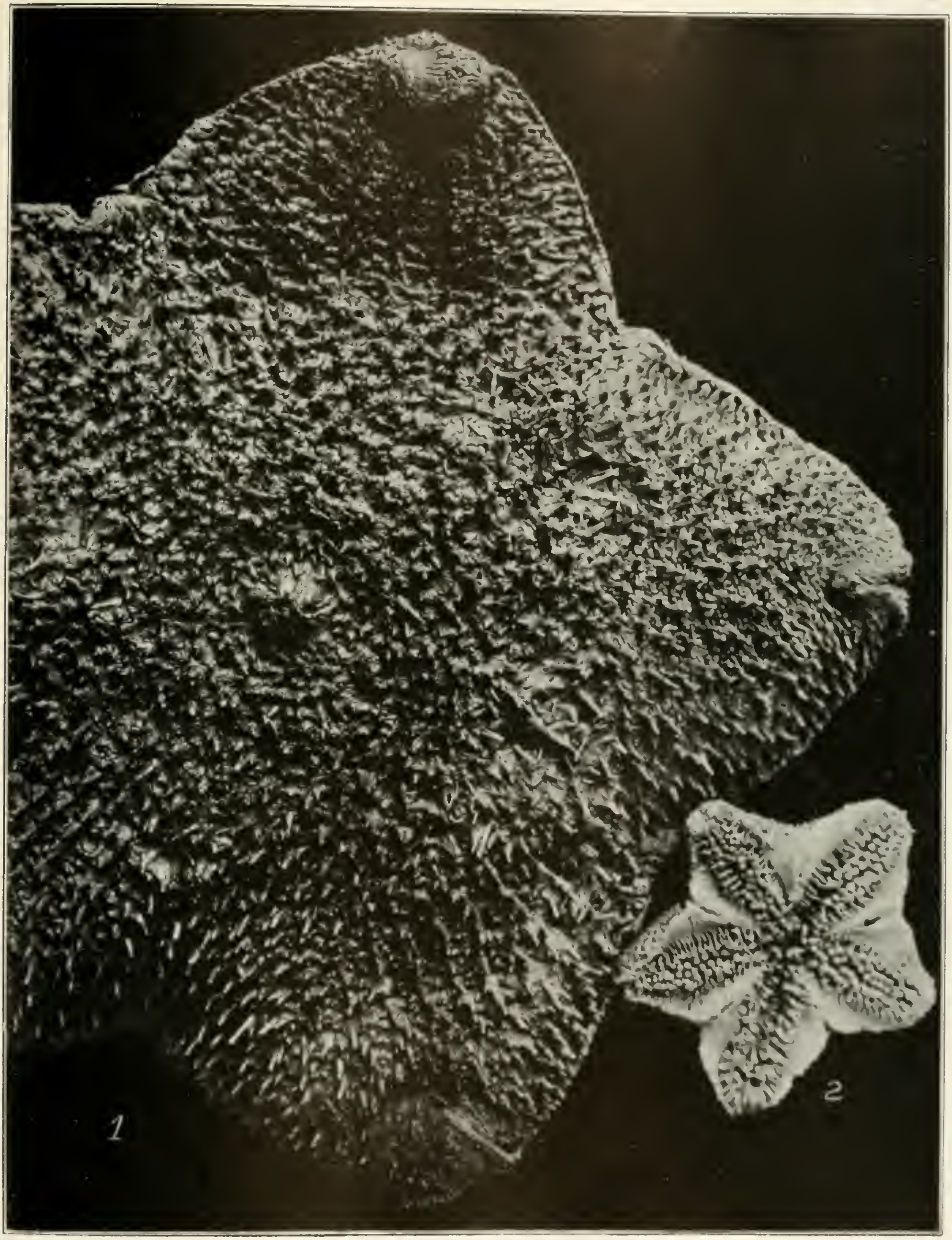
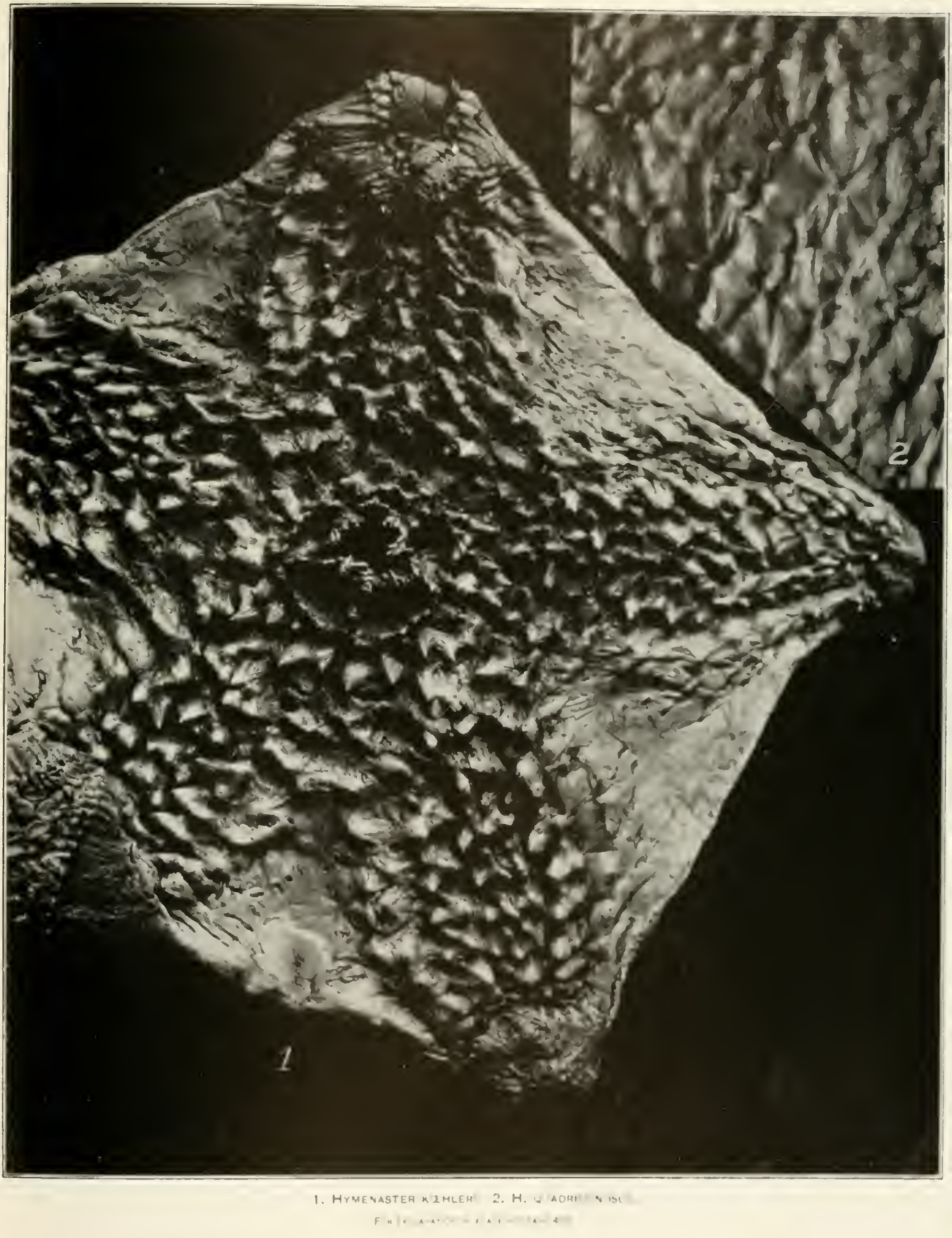


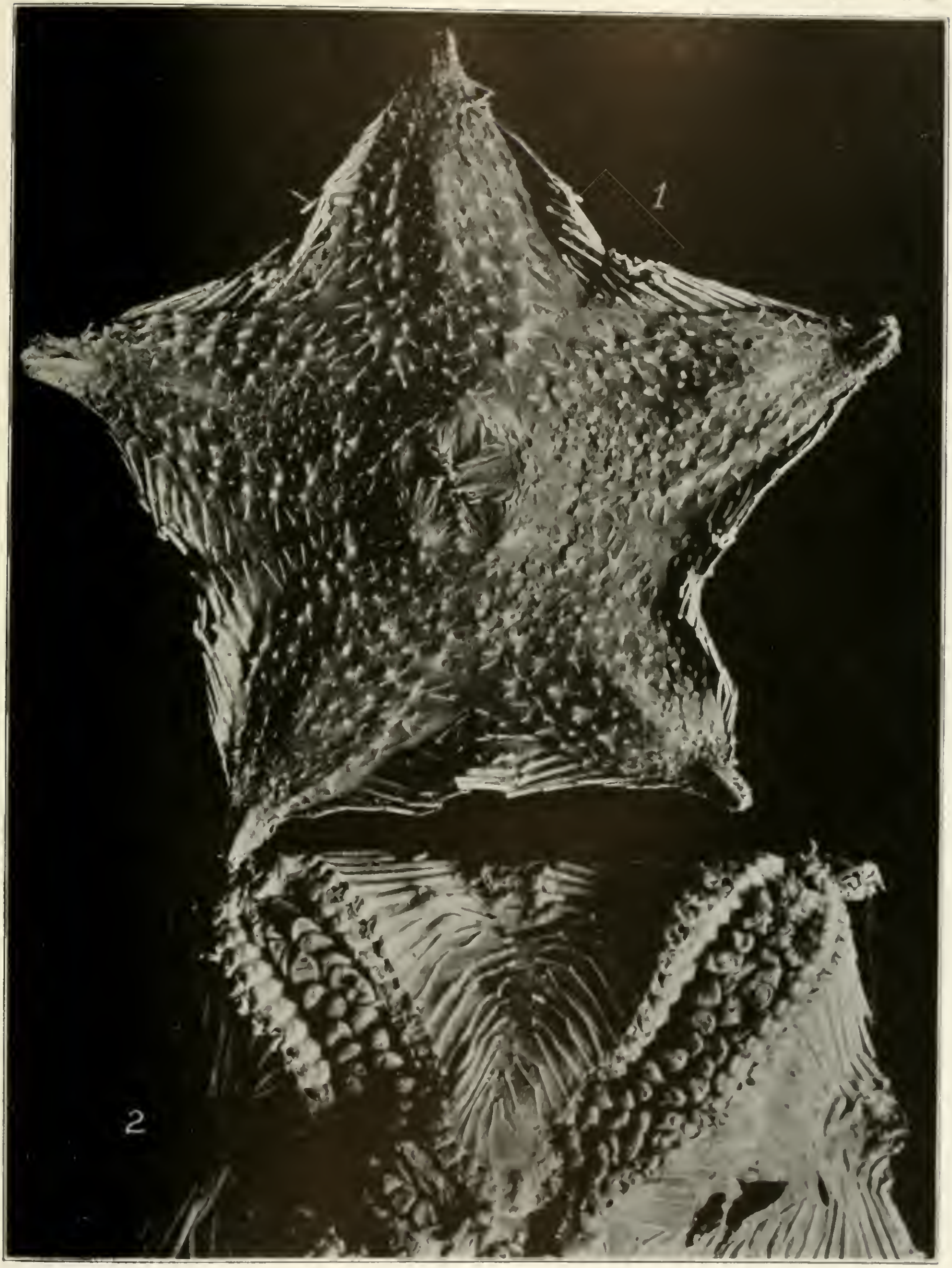
DIPLOPTERASTER MULTIPES.

FOR EXPLANATION OF PLATE SEE PAGE 403.



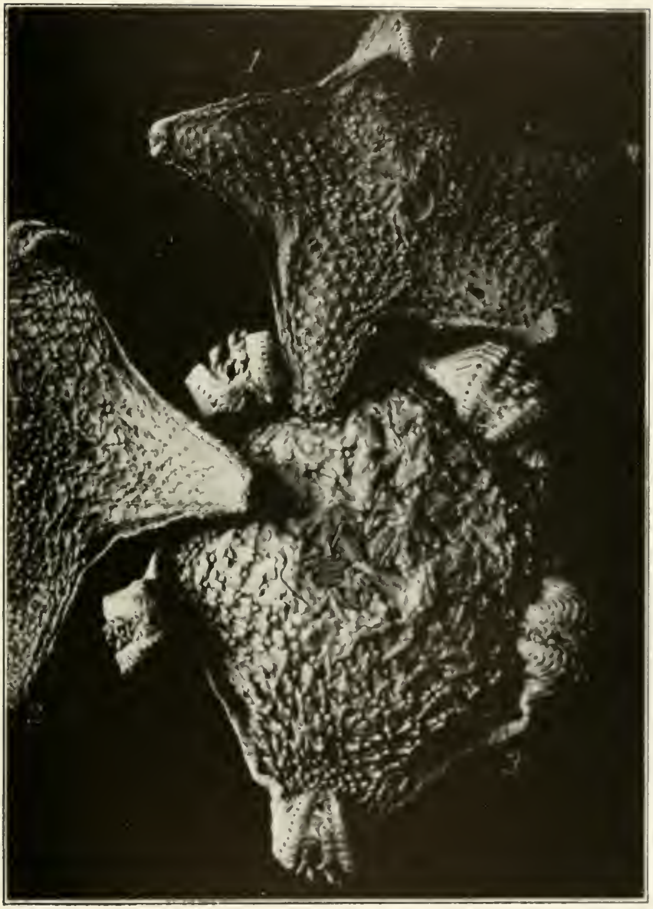
1. Hymenaster koehleri. 2. H. quadrispinosus.

For explanation of plate see page [illegible]



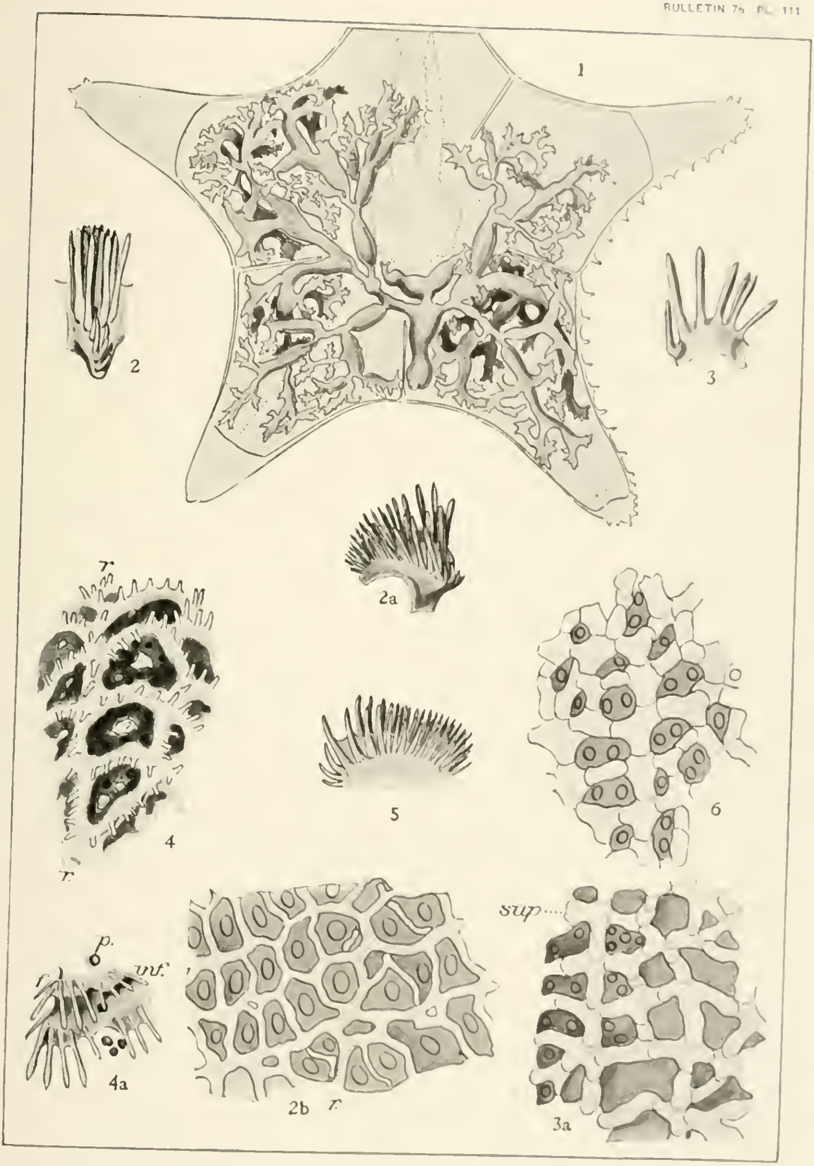
HYMENASTER PERISSONOTUS.

For explanation of plate see page 403.



HYMENASTER QUADRISPINOSUS.

FOR EXPLANATION OF PLATE SEE PAGE 403.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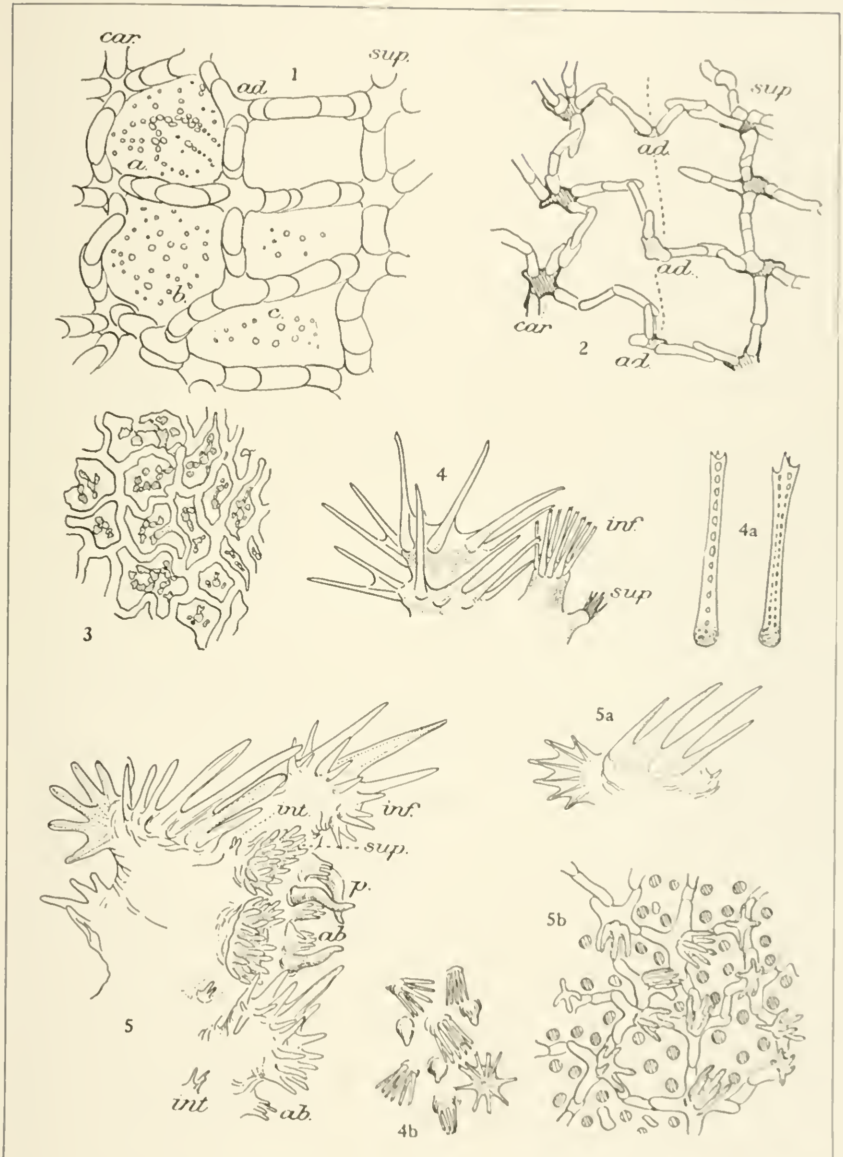
1. Dendrogaster arbusculus. 2. Henricia polyacantha. 3. H. longispina. 4. H. asthenactis. 5. H. clarki. 6. H. leviuscula.

For explanation of plate see page 404.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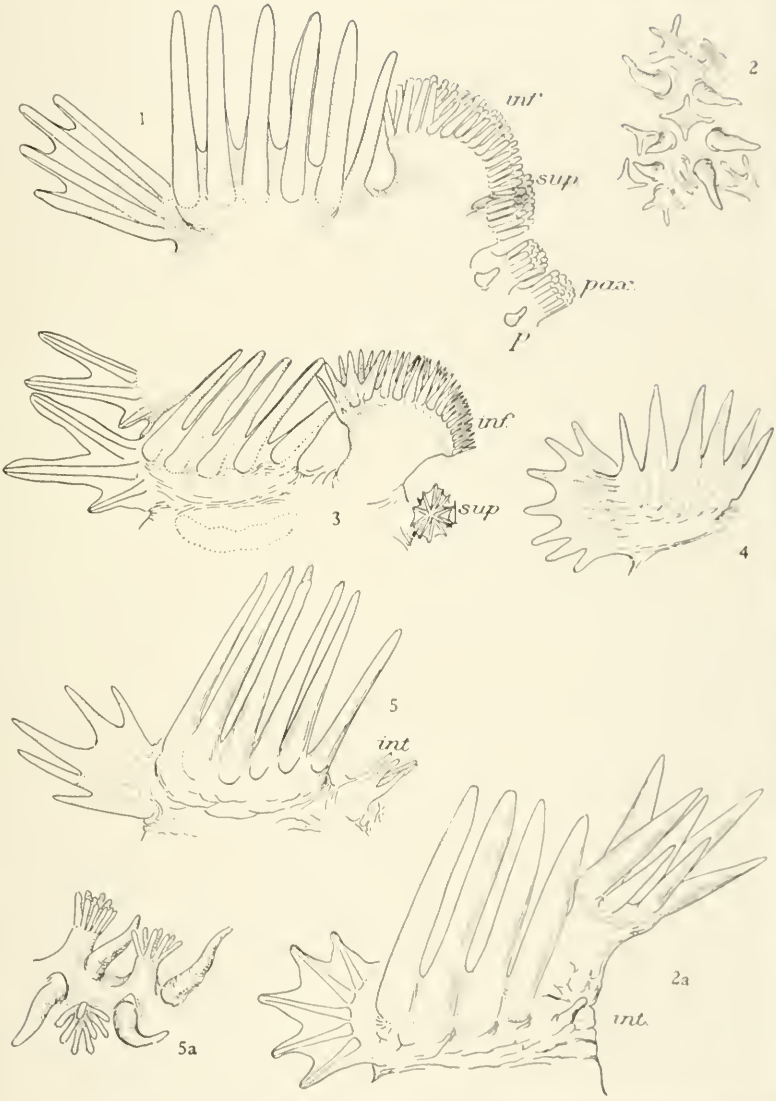
1. Poraniopsis inflata. 2. P. inflata flexilis. 3. Henricia clarki. 4. Solaster exiguus. 5. Heterozonias alternatus.

For explanation of plate see page 404.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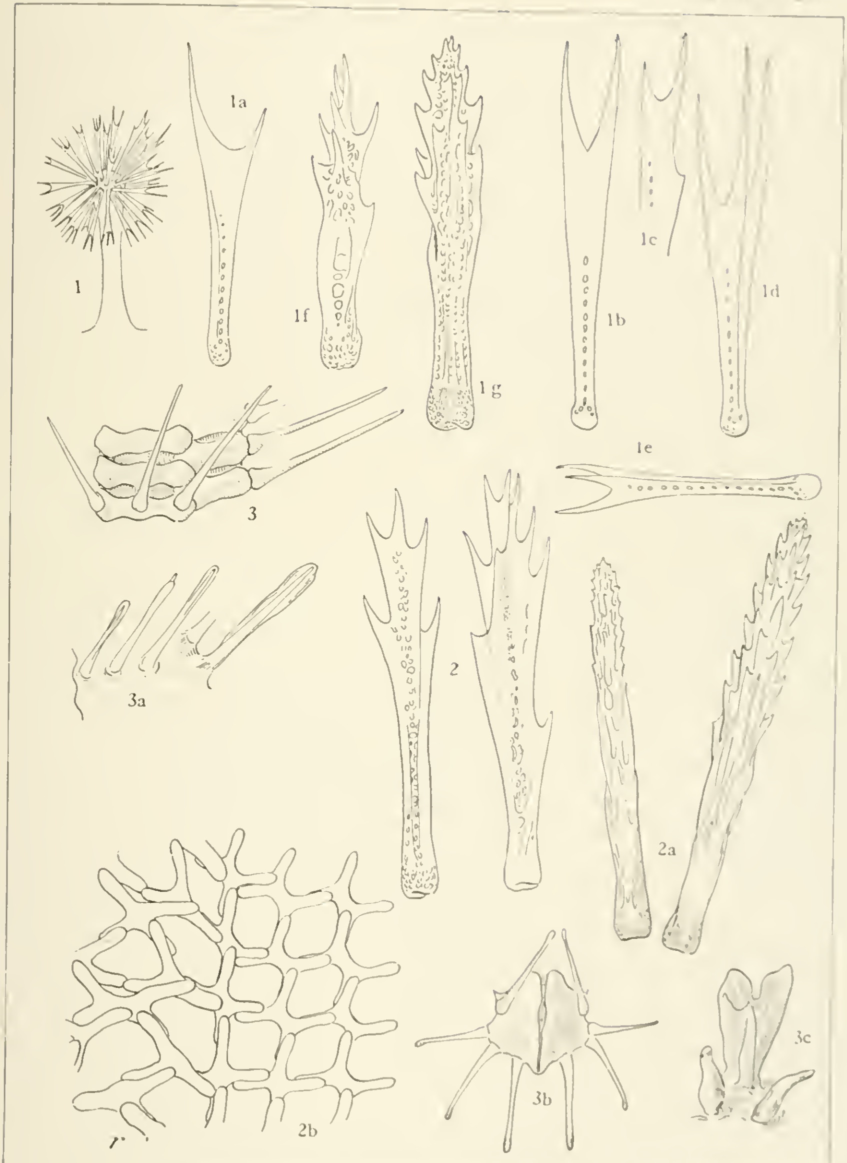
1. Solaster dawsoni. 2. S. borealis. 3. S. paxillatus. 4. S. japonicus. 5. S. hypothrissus.

For explanation of plate see page 404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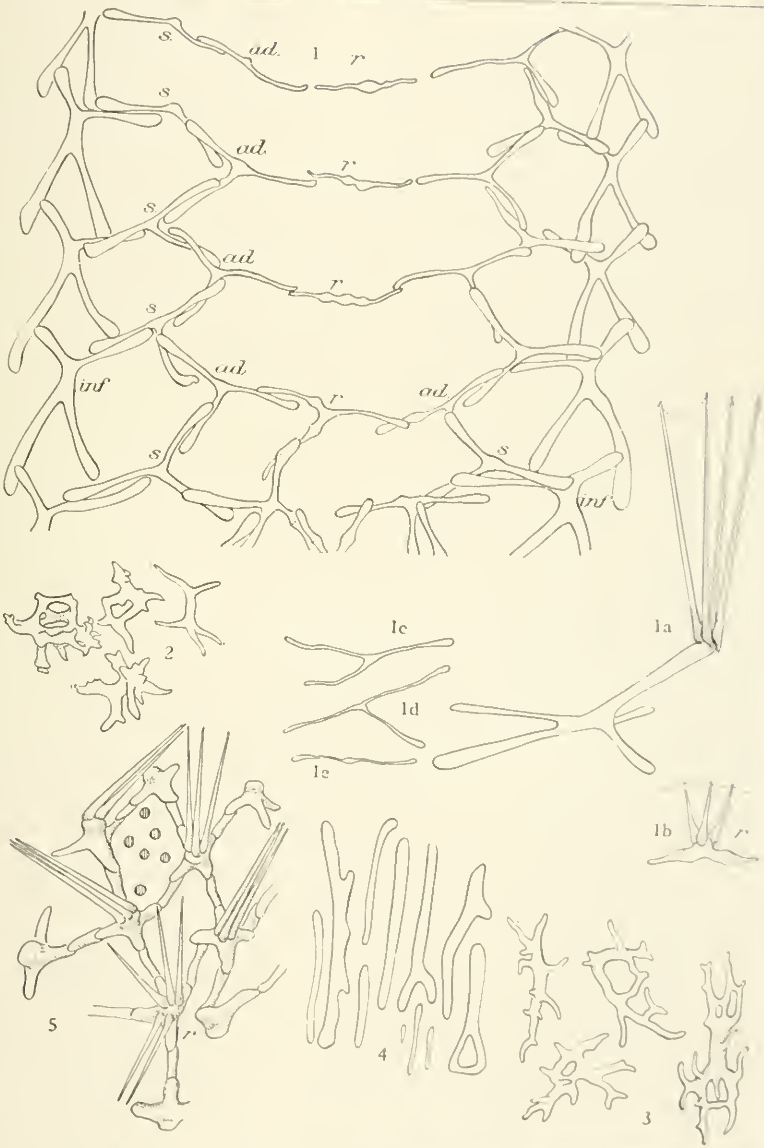
1. Lophaster furcilliger. 2. L. furcilliger vexator. 3. Peribolaster biserialis.

For explanation of plate see pages 404, 405.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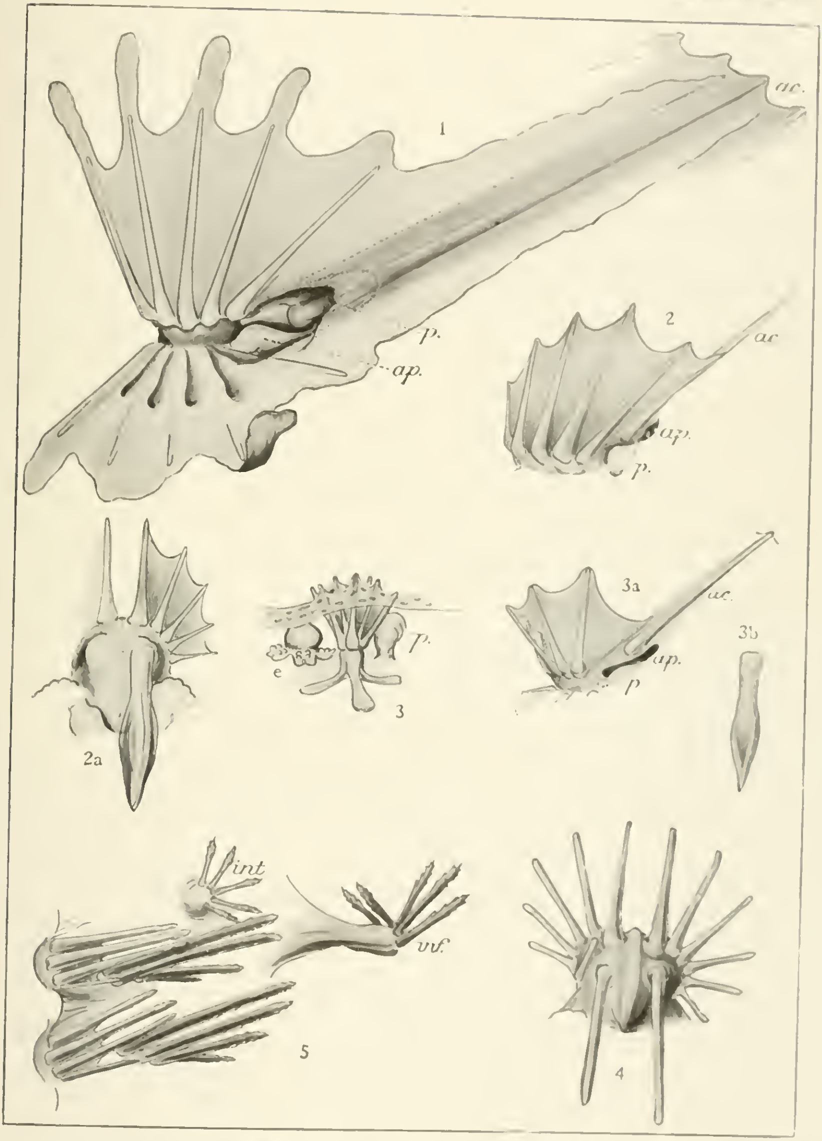
1. Hymenaster perissonotus. 2. Pt. trigonodon. 3. Pt. temnochiton. 4. Pt. marsippus. 5. Pteraster. borealis.

For explanation of plate see page 4[illegible]5.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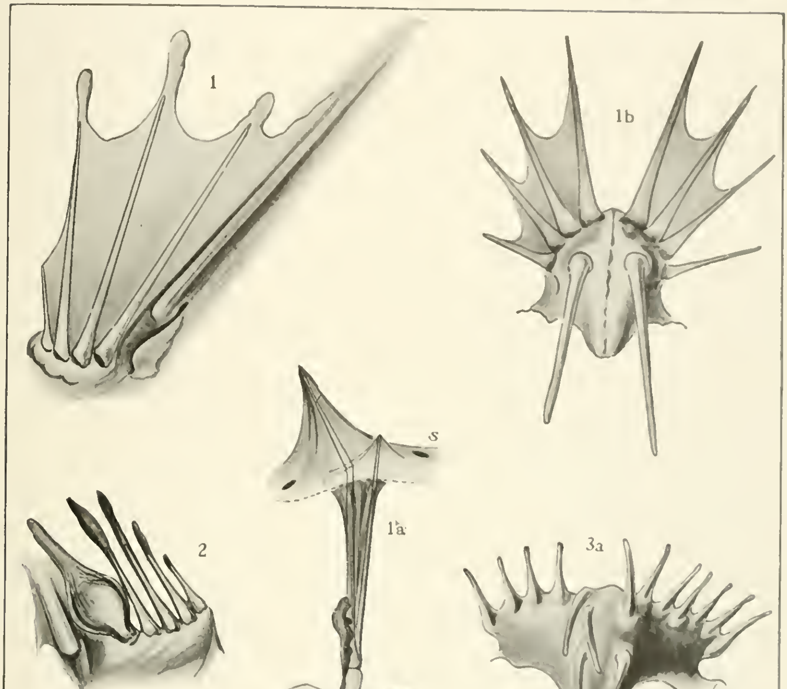
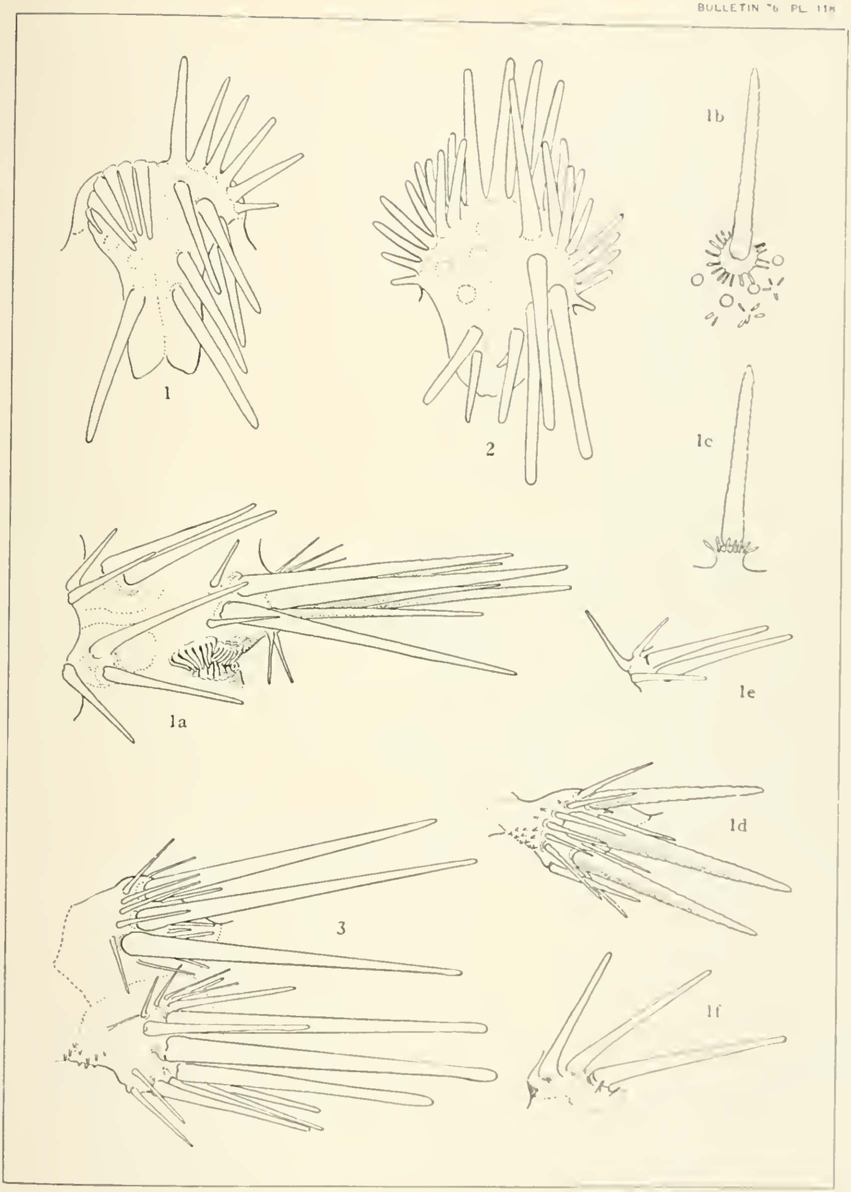
1. PTERASTER MARSIPPUS. 2. PT. TRIGONODON. 3. PT. TEMNOCHITON. 4. PT. [illegible] 5. L. [illegible]

[illegible]



1. PTERASTER JORDANI. 2. HYMENASTER QUADRISPINOSUS. 3. H. PERISSONOTUS. 4. H. KŒHLERI.

FOR EXPLANATION OF PLATE SEE PAGE 4[illegible]5.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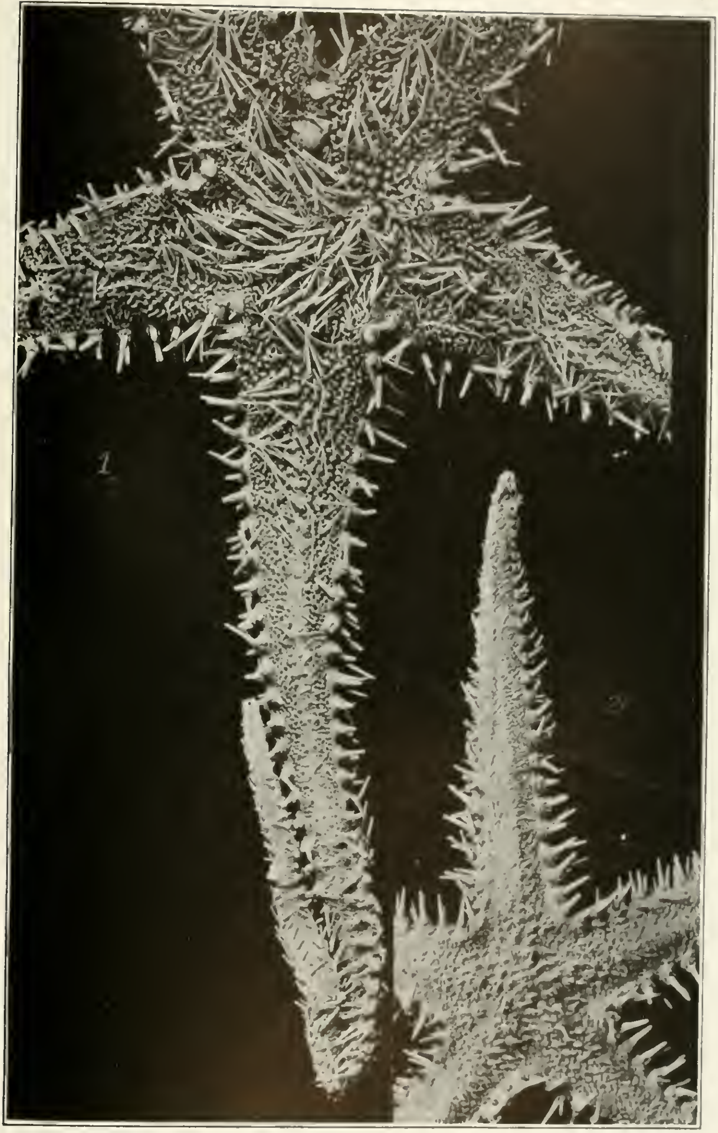
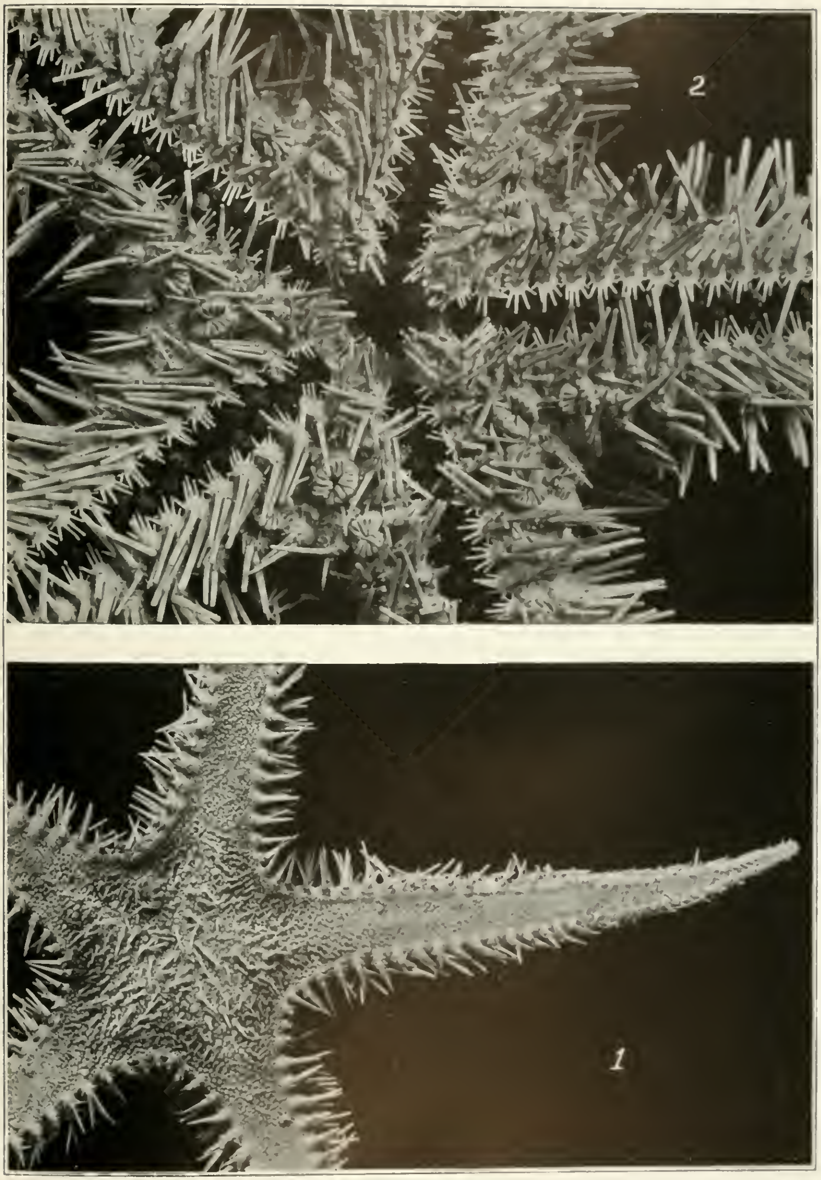
1. Myonotus intermedius. 2. Nearchaster pedicellaris. 3. N. aciculosus.

For explanation of plate see page 405.



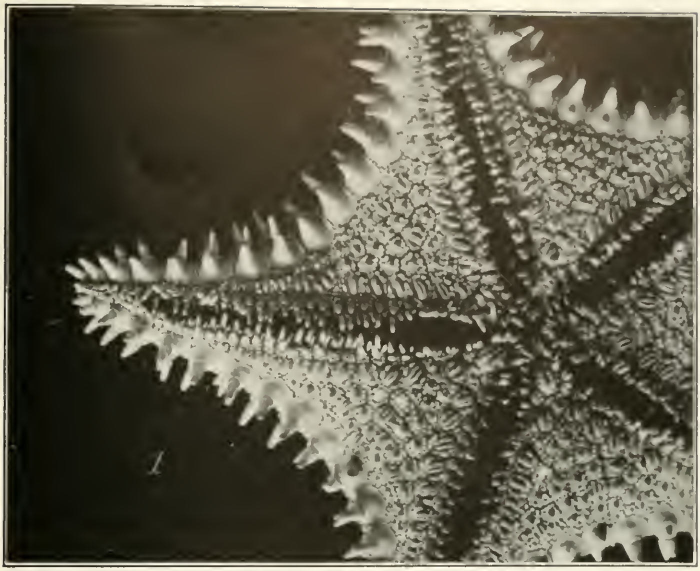
1. NEARCHASTER VARIABILIS. 2. LUIDIASTER DAWSONI (YOUNG).

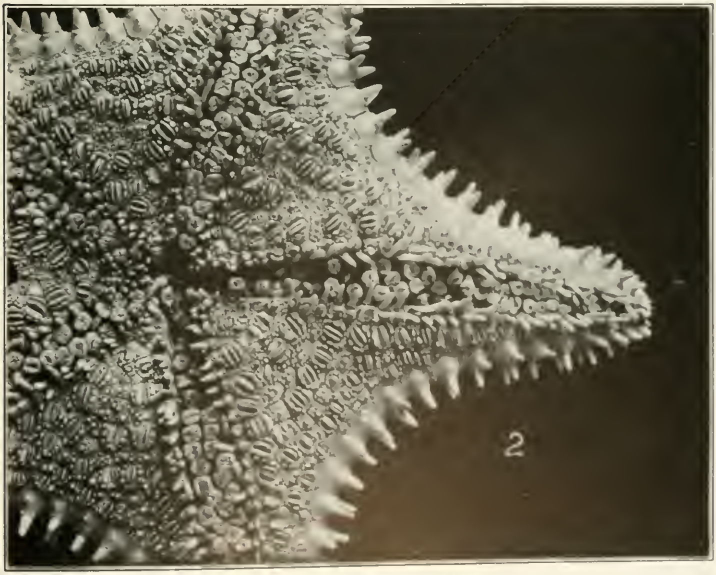
FOR EXPLANATION OF PLATE SEE PAGE 406.



LUIDIASTER DAWSONI

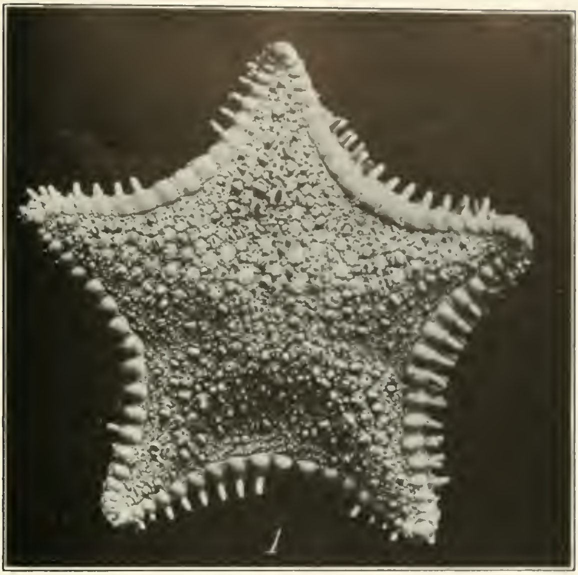
FOR EXPLANATION OF PLATE SEE PAGE 406

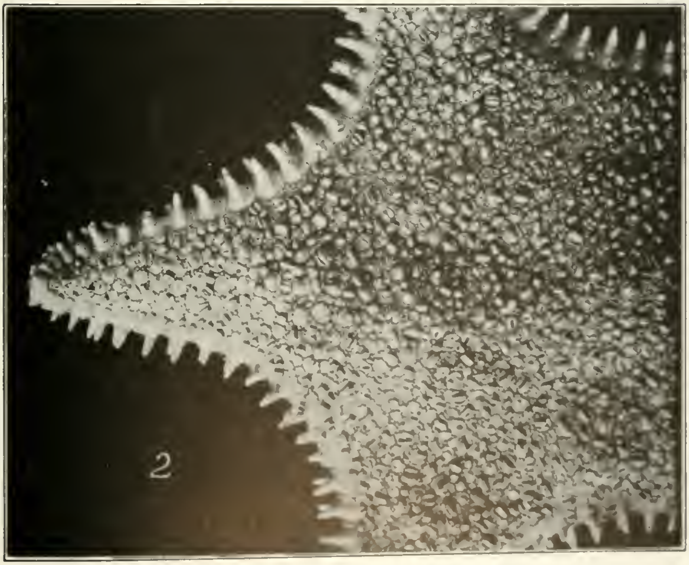




1. Hippasteria spinosa kurilensis. 2. H[illegible]elta armata.

For explanation of plate see page [illegible].





HIPPASTERIA LEPTOPELTA ARMATA. 1, YOUNG

FOR EXPLANATION OF PLATE SEE PAGE 40[illegible]

INDEX.

The following index contains the names of the orders, families, genera, species, and subspecies of Asteroidea which occur in this memoir. Two kinds of type are used for the names, roman and italic; the former indicates valid names, the latter synonyms. But when a species name follows a genus name that is a synonym of another genus name, both the genus and species names of the combination are italicized, although the species name may be valid. Two kinds of type are used in the figures referring to the pages; the heavy-faced type indicates the pages on which descriptions may be found. The names occurring in the explanation of plates have not been indexed, as the easiest method of finding all the figures of a given species is to turn to the page on which the description occurs, where a list of figures is indicated.

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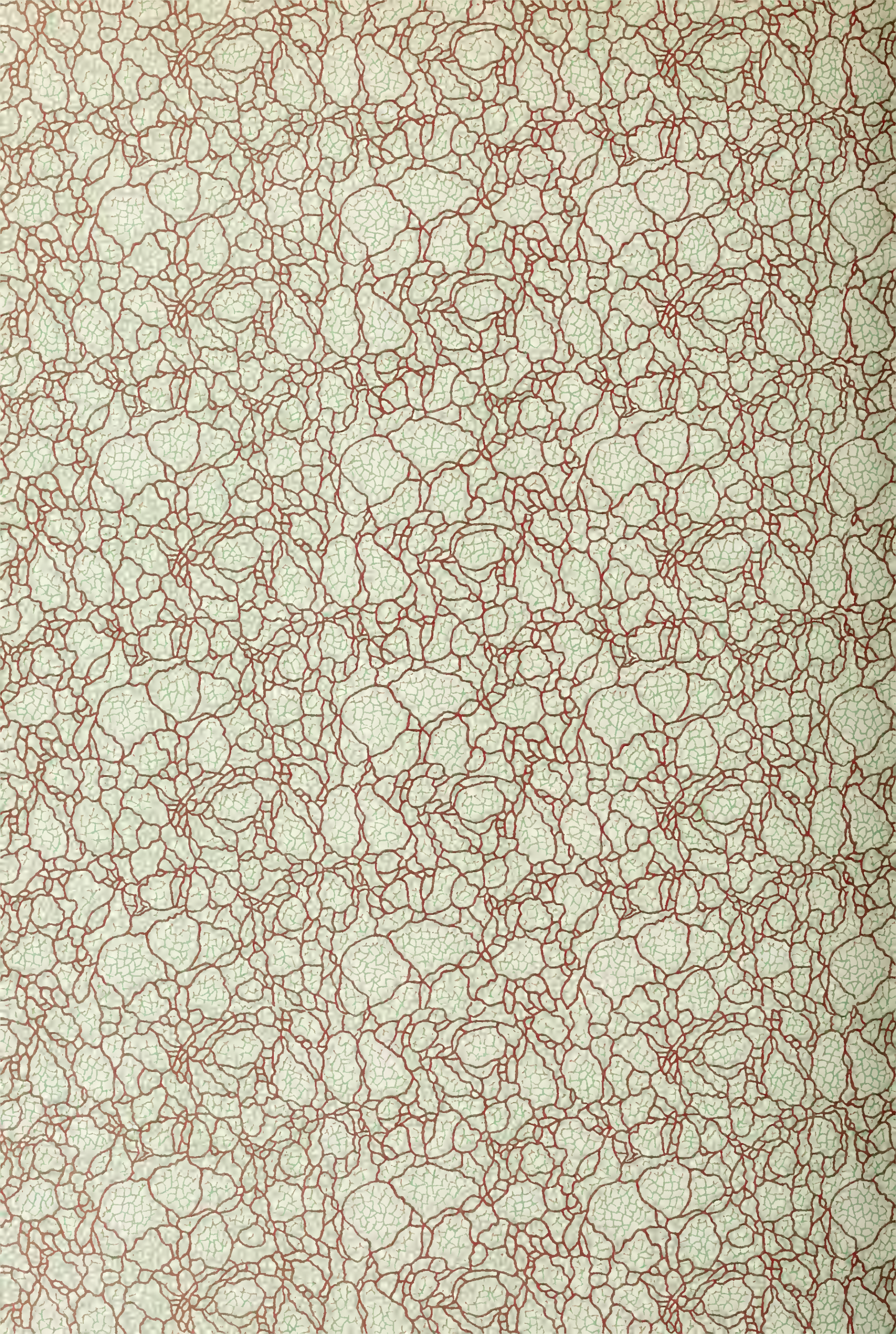

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